Arab American University
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Mapping Health Electronic Registries and Surveillance in Palestinian Ministry of Health Toward the National e-Health Strategy

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This thesis was submitted in partial fulfilment of the requirements for the Master's degree in Health Informatics

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Thesis Approval

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Declaration

This thesis was submitted in partial fulfilment of the requirement for Master's degree in Health Informatics.

I declare that the content of this thesis (or any part of the same) has not been submitted for a higher degree to any other university or institution.

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Dedication

To my beloved family for their endless support.

To the soul of my beloved brother Radwan.

To the Palestinian children who struggle to reach their schools because of the disgusting occupation.

To each student who works after studying hours to cover his or her study fees.

To the Palestinian prisoners who came out from under ground to breathe freedom. Ali Alhelou

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Abstract

Palestinian Ministry of Health built and developed many electronic applications and systems since its start in 1994 to capture administrative, financial, and health data for the sake of improving healthcare quality services presented to the Palestinian people. Availability and interoperability of such electronic systems would play a significant and primary role in providing healthcare services and therefore achieving good health outcomes. data sharing among such different electronic registries and systems is weak, and therefore the needed data by healthcare professionals and other stakeholders is not complete and not available at the right time and cannot rely on it for decision-making due to the lack of interoperability among these electronic systems since they have different data formats, in addition to challenges of privacy and security.

This descriptive study mapped the current health electronic registries and surveillance systems in the Palestinian ministry of health toward the achievement of the National Ehealth Strategy that has the goal to govern these electronic health systems and gives the needed support for all governmental, and non-governmental institutions that intersect with health system at the national level. This research examined the literature and reviewed previous studies related to the subject by searching different search engines such as PubMed, Google Scholar and other websites available on the internet to enrich the research and attain its goals.

This research proposed a data warehouse framework plan that has many layers, to make data available whenever requested by extracting it from different data sources in the ministry using Zinnar as an interoperability framework (ontology framework) that was developed by the Palestinian government to ensure data integrity and facilitate sharing

between different ministries and institutions, the framework plan utilizes the Palestinian governmental network X-Road for securing the exchange of data. It also suggests an intermediate Application Programming Interface layer to facilitate interoperability and guarantee the needed format of the exchanged data.

The usage of Extraction, Transformation, and Loading layer suggested by this proposed framework plan to ensure standardized data format, in addition to data dictionary and data marts to ease the utilization of the data warehouse by different stakeholders and to provide them with efficient access and analysis. Because of the complexity and the sensitivity of health data, this proposal advises the adoption of advanced machine learning and data mining tools to extract meaningful insights and ideas that would not be figured out by human or traditional analysis for better management and treatment. It also suggests the utilization of a Chatbot to provide intended users with a seamless access to relevant data when needed.

Table of Contents

List of Figures

List of Appendices

List of Abbreviations

AI	Artificial Intelligence
API	Application programming interface
CPD	Continuing Professional Development
CT	Computed Tomography
DHIS2	District Health Information Software 2
DICOM	Digital Imaging and Communication in Medicine
DSS	Decision Support systems
DW	Data Warehousing
ED	Emergency Department
EHR	Electronic Health Record
EMR	Electronic Medical Record
ESCWA	Economic and Social Commission for Western Asia
ETL	Extract, Transform and Load
EU	European Union
FHIR	Fast Healthcare Interoperability Resources
GDHI	General Directorate of Health Insurance
GDPR	General Data Protection Rule
GHI	Governmental Health Insurance
GHI-MIS	Government Health Insurance Management Information System
GIS	Geographical Information System
HIMSS	Healthcare Information and Management Systems Society
HIPAA	Health Insurance Portability and Accountability Act

HIS	Health Information System
HISs	Health Information Systems
HIT	Health Information Technology
HL7	Health Level 7
HRHO	Human Resources for Health Observatory
ICD	International Classification of Diseases
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronics Engineers
IoMT	Internet of Medical Things
ISO	International Organization for Standardization
IT	Information Technology
MCH	Maternal and Child Health
ML	Machine Learning
MOF	Ministry of Finance
MOI	Ministry of Interior
MOL	Ministry of Labour
MOSD	Ministry of Social and Development
MRI	Magnetic Resonance Imaging
MTIT	Ministry of Telecommunication and Information Technology
NLP	Natural language Processing
PACS	Picture Archiving and Communication System
PHCs	Primary Healthcare Clinics
PHI	Protected Health Information
PMC	Palestine Medical Council

PMC-EAS	Palestine Medical Council E-Learning and Accreditation System
PMoH	Palestinian Ministry of Health
PNIPH	Palestinian National Institute of Public Health
QR	Quick Response
RTA	Road Traffic Accidents
SOAP	Simple Object Access Protocol
SWOT	Strengths, Weaknesses, Opportunities, and Threats
UDDI	Universal Description, Discovery, and Integration
UHC	Universal Health Coverage
WHO	World Health Organization
WSDL	Web Services Description Language
XML	Extensible Markup Language

Chapter One

Introduction

1.1 Background

The issue of data availability and interoperability in healthcare systems was always of high priority concerns of top management working in health domain. Interoperability in healthcare setting is a big challenge worldwide because of the lack of standards among different health organizations, data is stored in different locations, and the sensitivity of healthcare data in term of security, privacy, and confidentiality. Availability of good and valid information on the other hand at the needed time for decision and health policymaking contributes to the quality of health services provided to people and serves efforts towards achieving the sustainable development goals (SDGs) mainly the goal concerns about achieving universal health coverage. It can also reduce medical errors, save time and resulting in better patients' safety and affecting the health status of the whole population positively.

Electronic information is expected to change the face of future medicine but the majority of the current medical information lack interoperability because data is fragmented and stored in various databases, applications are incompatible, in addition to the implications imposed by the ownership of software. This makes sharing, analyzing and interpreting of information a hard process and therefore influences the development of medical sector and reduces the potential use of emerging technologies such as Artificial Intelligence and Big Data (Lehne et al., 2019).

Accurate, valid, and reliable information is needed by Healthcare policy makers to help them better understand health related problems and provide them with the evidence needed to figure out patterns and trends for planning and quick response with the right interventions (Rashidian et al., 2017).

In health settings, it is difficult to manage public health and an aging population, so providing them with good health services and treatments without the availability of population data in a timely manner would not be an easy task. One of the main obstacles regarding this issue is the difficulty of accessing data stored in electronic health records (Mandl et al., 2020).

Exchanging of health information, in a secure way will contribute to reduce paper work that leads to reduction in cost and increases the quality of services provided, and therefore better diagnosis, and better treatment.

Interoperability is crucial in enhancing the care and treatment of patients. Giving access to accurate and valid data at the right time enables providers of healthcare to take right decisions based on a detailed aggregated information gathered from different available health information applications.

The current revolution of information technology highly affected electronic health records in a positive way mainly the provision of international standards regarding the interoperability between systems that utilize complex information of patients (Evans, 2016).

Data availability and interoperability help the health sector to work in an effective way as a connected system that contributes to overcome the problem of fragmentation and duplication of delivery of health services. They increase the

ability of providers of healthcare to use various systems, save time and work efficiently.

Palestinian Ministry of Health (PMoH) has many electronic systems that collect administrative, financial and medical data. Avicenna is the most important electronic system that collects data about patients from day of admission to day of discharge and store it in an electronic medical record. Another significant application is Picture Archiving and Communication System (PACS) that manages the different medical images and makes them available to be retrieved and examined by healthcare professionals. Governmental Health Insurance Management Information System (GHIMIS), and E-referral are of high importance to Palestinian health policy and decision makers as well as Palestinian people; GHI-MIS allows Palestinian people who are insured to get care from Palestinian ministry of health facilities such as hospitals and primary healthcare clinics, whereas E-referral system transfers patients who are legible according to PMoH policies and regulations to be treated outside the governmental centers since the service or wanted procedure is not available locally (in PMoH hospitals).

Achieving interoperability among these various electronic systems supports informed policy and decisions by allowing access to timely, reliable and comprehensive reporting on various activities and outcomes of the healthcare system in Palestine. Making data generated from such systems available and interoperable contribute to the implementation of the National E-health Strategy by paving the way to address its seven components: leadership and governance, strategies and innovations, ICT (Information and Communications Technology) services and applications, infrastructure, Standards and interoperability, Legislation,

policy, and compliance, in addition to workforce (Palestinian ministry of health, 2022).

Providing electronic services based on aggregated data collected from different existing digital applications serves individuals, providers of healthcare, and policy makers. It also enables different stakeholders' players in the Palestinian health context to gain access, utilize and exchange healthcare information that allows them to provide such services in novel approaches.

Since PMoH is the main supplier of health services in Palestine, making different electronic systems share and exchange data among each other will influence the adoption of interoperability at the national level as recommended by the National E-health Strategy.

Because sharing of data is highly important to Palestinian government to present good services to Palestinian people, it adopted many initiatives to help all ministries including ministry of health to exchange information between each other's in a secure way. It encourages them to transform their services to digital ones using a governmental portal named Houkomty (ministerial committee of government e-services).

Some of these governmental initiatives are Information Security Policy document, Tech and Management cluster, the use of electronic governmental e-mail and the internet, the sectorial strategy for telecommunication and information technology 2021-2023, and the sectorial strategy for health 2021 – 2023. It also issued many Decrees bylaw such as Electronic Crimes Decree bylaw number 10 for the year 2018, the Right to Access Information Decree bylaw for the year 2018 and the electronic transactions decree bylaw for the year 2013.

The electronic health systems in PMoH have many challenges as other healthcare systems in the world, the Palestinian healthcare systems are even more challenging based on the uniqueness of the Palestinian situation as a country under occupation that relies mostly on donors, the limited resources make the functionality of the current digital applications even more complex. This study suggests collecting data from different data sources running by PMoH and store it in one place after cleaning and transforming it to the needed standards and formats according to PMoH regulations and policies; based on the ministry needs the different electronic systems build their own Application Programming Interfaces (APIs) to define data elements related to them and exchange requested data to facilitate interoperability.

The author proposed a data warehouse framework plan to overcome the challenges of sharing data among the electronic systems currently used by PMoH based on: the health standards, terminology and classifications utilized in the ministry, governmental interoperability framework (Zinnar), and a governmental network (X-Road) as a data exchange layer.

1.2 Problem Statement

Interoperability and availability of health information are crucial for providing good care and raise the quality of treatment of patients since they allow for data sharing among different existing information systems. They enable decision and policy makers to better plan for future health of the population. In the Palestinian ministry of health there is a Lack of usage of information derived from the current existing e-registries and surveillance systems for making decisions, guiding health policies and improving quality of health services.

The study explored the availability of health data and its readiness to be shared and exchanged among different beneficiaries securely in an interoperable network. Limited access of academia, researchers and different healthcare providers to the existing data might duplicate efforts in collecting data, which are available but not visible.

1.3 Research Question

The main research question is, "Mapping the existing e-health applications in PMoH towards the development of national e-health strategy", the issue of interoperability and sharing data is a main component in such strategy, so the study examines the existing electronic systems, explores their functions, and the quality of data collected to enhance the exchange of such data among them and check the ability of solving the issue of interoperability.

The following questions will help to achieve the main study question:

- What is the status of data sharing among the existing electronic systems in PMoH?
  - Could interoperability be achieved according to the existing challenges?
- What is the condition of the current data quality and integrity in PMoH electronic systems?

1.4 Significance of the Study

The importance of this study comes from the importance of health itself and the power of accurate and timely data in developing and planning for the future of health in Palestine.

Real-time information and exchange of data among different stakeholders will lead to better decision making and have a good impact on the quality of health services presented to the Palestinian people.

The State of Palestine is committed to work toward achieving universal health coverage, which is one of the essential Sustainable Development Goals mainly the third one that aims to ensure healthy life and promote well-being for all at all ages.

The significance of the study also comes from the uniqueness of the Palestinian health system as a donor driven system and the challenges that faces because of the Israeli occupation, as well as the role of technology and electronic systems in reducing cost and improving health.

The diversity of the Palestinian health system and the need for better health information sharing through interoperable electronic systems and the availability of patients' data on time will contribute to better diagnosis and treatment and improve access to healthcare services. The importance of exchanging data and having it on time appeared clearly during the fight against Covid-19 (corona virus), it can save lives.

1.5 Aim of the Study

The main aim of this research is to map electronic health registries and surveillance systems used in Palestinian ministry of health in terms of interoperability and availability.

1.5.1 Specific Objectives:

1- Explore the available e-registries and surveillance to find out if they comply with the objectives of the national e-health strategy in order to facilitate interoperability among them and ensure the availability of generated health data.

2- Define current challenges in the Palestinian health system and its impact on ehealth in term of interoperability and availability.
3- Present knowledge frame based on interoperability and availability to control the status of these e-registries to comply with the national e-health strategy.
4- Develop recommendations to contribute to the national health strategy presented by ministry of health to achieve better services through interoperable electronic systems that facilitate the access to health data when needed.
5- Define new source for information by adopting interoperable electronic systems and ensuring access to healthcare data to provide researchers, care providers, and related stakeholders with all needed information.

1.6 Summary

Chapter1, an introductory chapter that has the study background, problem statement, objectives and significance of the study.

Chapter 2, contains previous studies, review of literature related to the electronic systems in term of interoperability and availability and factors affected these two dimensions. Factors such as challenges and barriers as well as standards such as Health Level 7 (HL7) and Digital Imaging and Communication in Medicine (DICOM), in addition to the conceptual framework that illustrates the different variables and concepts used all over this thesis.

Chapter 3 explains the methodology used in this research and the outcome of the study which is a proposed healthcare data warehouse composed of different layers to solve the issues of interoperability and data availability in the PMoH.

Chapter four clarifies the proposed Palestinian e-health data warehouse, explains the strategic goals behind adopting such solution, identifying the main data sources, the attributes of it as well as the different main components.

The final chapter includes discussion and recommendations for better use of electronic health systems in order to have good quality of care based on informed decisions and evidence-based planning that built on the analysis and deep mining of the data in the warehouse for the sake of improving the health of the Palestinian people.

Chapter Two

Literature Review

2.1 Introduction

This chapter sheds light and reviews topics linked to the study in terms of interoperability and availability. It defines the terms interoperability of electronic and surveillance systems as well as availability of healthcare data, it shows different types of interoperability and obstacles facing implementation as standardization, confidentiality, privacy and security. It illustrates concepts of data compliance and openness to make sure that healthcare data sharing among different stakeholders happen according to regulations from authorized people. This chapter also discusses methods of standards such as HL7, Application Programming Interfaces (APIs), Web Services, and DICOM.

2.2 Electronic and Surveillance Systems

Information technology applications, e-registries, surveillance, and electronic systems are all related to health data management and currently intersect with most aspects of people's life especially in healthcare settings. They aim to help them in having good health and enjoying their life regardless of age.

Based on World Health Organization (WHO) first guideline on digital health interventions, released on April 2019, countries can apply electronic technology on health, accessed by different devices such as computers and smart phones to enhance the health of population and the quality of health services presented to people. As an example of digital intervention affects health positively is sending reminders to pregnant women to attend antenatal care appointments and having children return to vaccinations (WHO 2019).

Electronic, E-registries, and surveillance systems in the Palestinian ministry of health aim to serve and help in achieving the strategic goals of the Palestinian ministry of health.

These goals include but not limited to; guarantee the continuity of providing comprehensive healthcare for Palestinian people, improve the process of governance by enhancing coordination and integration among different stakeholders and institutionalize quality systems in all parts of providing health services.

Healthcare policies need valid and reliable data and accurate information for action. They help decision and health policy makers to better understand health related problems and provide them with the evidence needed to figure out patterns and trends for planning and quick response with the right interventions(Rashidian et al., 2017).

Good health information system at the national level is very crucial for providing reliable health data on time. Availability of such data will provide top managers with a very important tool for making right decisions, better management of resources, and effective planning of health systems and services. For this reason WHO has put tremendous efforts for the last decades to strengthen health information system in the Eastern Mediterranean region countries (Alwan et al., 2016).

A study investigated six digital databases: Scopus, MEDLINE, cumulative index to nursing and allied health literature, systematic reviews of Cochrane database, COMPENDEX, and Academic Premier. The researchers examined data from the different databases from 01/01/2000 until 31/03/2016. The article concluded, that the provision of public healthcare services needs to be re-engineered to cope with the emerging health informatics and technology and should focus on the capacity building of health workers for training and learning in the field of healthcare related technologies

such as health informatics. Surveillance applications that generate real time data and make it available in a timely manner are powerful tools in the fight against international pandemic spread of viruses such as Ebola and Zika. Covide-19 is a good example of the primary role of informatics, availability of evidence-based data, and surveillance applications in the battle against its spread and therefore minimize its effect on public health. The study indicated that barriers concern privacy and standardization of data, transfer of technology and interoperability are still exist (Williams et al., 2019).

According to a study uses the results from two surveys done by the internet and finished in the year 2015 that focused on healthcare providers and official in the public health sector covered seventy-six countries worldwide that dealt with mother and child health and interested in reducing the mortality rate. The study assured that lack of available data needed for managing mother and child health led to slow achievement in decreasing down the mortality rate. So, having the needed data on time will reduce the mortality rate as well as the morbidity for both children and pregnant women. Securing the information and protecting the privacy is a must due to the sensitivity of the data collected for reproductive reasons; that's why regulatory measures and ethical consideration should be taken to control the governance of data when dealing with mother and child health through electronic registries (Myhre et al., 2016).

The integration and interoperable of such different electronic systems operating in various locations are very significant in order to gather information in a single place to stop creation of any duplicate data and to provide policy and decision-making people with reliable and accurate source of data to take the right actions based on real time information.

Using available data provided by the electronic system or registry for the follow up of antenatal period can guarantee the completeness and reliability of such data more than any other data sources(Friberg et al., 2019).

2.2.1 Electronic and Surveillance Systems in PMoH:

There are three types of electronic systems running in different facilities in PMoH:

- Outsourcing electronic systems that developed and implemented by third party Information Technology (IT) companies either locally or outside the country.

  These electronic systems built and developed according to the ministry's requirements but funded by different donors or international organizations.

  Applications such as Avicenna, Picture Archiving and Communication System (PACS), Governmental Health Insurance Management Information System (GHIMIS), and E-referral are all examples of such electronic systems.
- In house electronic systems: these systems developed internally by IT team in the ministry of health, controlled totally by them, and funded by the government such as Drug Management System, result.moh.ps site that provides people with the result of their covid-19 tests and instructions of what to do if the result is positive, and vaccine.moh.ps that manages Covid-19 vaccination process.
- Open source electronic systems: the systems adopted by PMoH mainly for the primary healthcare facilities. District Health Information Software 2 (DHIS2) is an open source platform customized and implemented as a joined effort between PMoH and Palestinian National Institute of Public Health (PNIPH) by a core technical and IT team from both sides. Many applications built upon this platform such as Maternal and Child Health (MCH), Mammography, and Covid-19

Surveillance System.

Some of the digital applications are E-registries, some are electronic systems, and some are surveillance systems. They are all systems related to healthcare data management with various goals and functions. E-registries are applications specialized in collecting and storing healthcare data about chosen population or specific disease. The main aim of such applications is to follow and monitor outcomes of health such as monitoring cancer or diabetes.

Electronic systems involve various healthcare digital tools to manage wider scope such as Electronic Health Records (EHR) and Electronic Medical Record (EMR) that deal with data related to patients as well as telehealth platforms and health information exchange. The main goal of such applications is to enhance the quality of healthcare services by providing up-to-date health data.

Health surveillance systems on the other hand are tools to follow and monitor any varies in the pattern of specific diseases and their impacts on population health. These applications track the spread of an infectious disease, and study its behavior overtime, by utilizing collected data from electronic health systems or other data sources such as eregistries.

The different digital systems running in PMoH use many healthcare standards such as HL7, DICOM, and international classification of diseases. Avicenna based on HL7 healthcare standard in addition to that it utilizes International Classification of Diseases (ICD10cm and ICD9) for both diagnoses and medical procedures, PACS based on DICOM format whereas DHIS2 supports many healthcare standards such as HL7, ICD, and Logical Observations Identifiers Names and codes (LOINC) that mainly used for laboratory tests and clinical data measurements.

2.3 Methods of Standards

2.3.1 Health Level 7 (HL7)

It is a group of predefined standards, which allows data exchange between health electronic systems such as patient health records and electronic health records by managing data type and structure. It is the most popular standards adopted in health settings (Oemig, 2019). Using HL7 contributes to data integrity by rising the quality, improving both completeness and timeliness (Metroka et al., 2014).

Countries of South Africa, Kenya, Malawi, and Ethiopia built a health information system called mHealth4Afrika used in both hospitals and health primary centers and use mobile technology to facilitate the access to health data. This health information system used the standard HL7 Fast Healthcare Interoperability Resources (FHIR), which is one of HL7 versions to achieve exchange of information between EMRs implemented in hospitals, and DHIS2 platform operated in primary healthcare centers.

The method used based on the built in HL7-FHIR service which developed by mHealth4Afrika in the year 2017 in order to allow and facilitate the exchange of information generated by medical sensors as well as laboratory orders and results between DHIS2 and EMRs. Native Application programming interface (API) provided by DHIS2 integrates other systems and allows them to exchange information with DHIS2 whereas FHIR API provided by FHIR enables other applications to access its resources. FHIR import/export service enables the resources offered by FHIR to be exchanged between DHIS2 and FHIR (Baskaya et al., 2019). Figure 1 shows the DHIS2 and FHIR model.

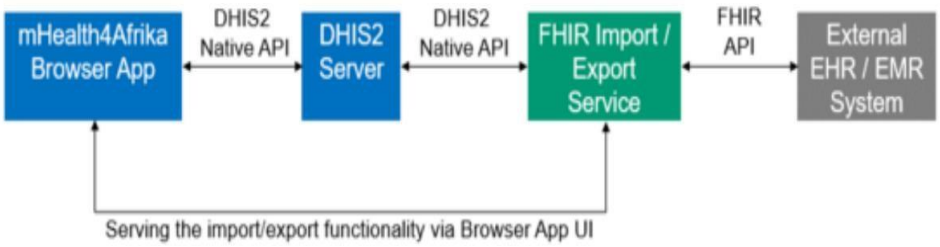

Figure 2.1: DHIS2 and FHIR Model, source: (Baskaya et al., 2019).

2.3.2 Application Programming Interfaces (APIs)

Wikipedia defines API as a kind of standard or a document, which specifies clearly how to make a link or an interface to connect two applications so they can exchange information in a secure way.

APIs usage to share patients' data is growing and can provide a big chance for institutions of healthcare, which require a secure channel to share patients' data. For the sake of developing APIs industry, many sociotechnical issues need to be addressed:

The interest in patients not only on providers, focus on write APIs not only read APIs, pay attention to FHIR since it is widely used in healthcare domain, expand the use of FHIR-based APIs from common clinical data sets to accommodate other elements of data, and highlights rules of governing data (Dullabh et al., 2020).

Researchers from India proposed a federal API-based integrated architecture for health data that utilize principles of Blockchain emerging technology, which capture any transaction between systems in an efficient way, permanently and accurately.

The proposed roadmap would allow the personal health record to access different applications connected to the network to get updates as needed. Patients' health record can get information from wearable devices, physicians, healthcare facilities, laboratories and radiology images. The system can map out different tracks to give permissions to enable transmission of data in an automated way whereas in some cases it needs

permission from patients to allow exchange of their own data (Balsari et al., 2018). APIs can play an important role to generate data from different social media applications such as Facebook and Twitter. Interested researchers can get data gathered through using

APIs related to users' locations, posts uploaded, newsfeed as well as demographic data (Lomborg & Bechmann, 2014). APIs can benefit from the huge amount of health data generated by the social media application; which researchers can use to improve public health.

The number of people use social media at the international level is 4.48 billion with a percentage of 56.8 (BACKLINKO, 2021).

2.3.3 Web Services

This technology enables two applications to interact based on protocols of communication, description of services, and discovery of services, installed over an existing web protocols and depending on open standards of XML (Siblini A web service is a standardized method that allows web-based applications through different open standards such as Extensible Markup Language (XML), Web Services Description Language (WSDL), Simple Object Access Protocol (SOAP), and Universal Description, Discovery, and Integration directory (UDDI) to describe web-services and integrate, therefore exchange data using the internet protocols regardless operating systems or programming language. XML used to define format of data, (WSDL) utilized to describe existing services, whereas SOAP is for transferring information and UDDI for determining the availability of services (Webopedia, 2021 & Mansour, 2005).

According to the general administration of information technology/ministry of health, 2021, the Palestinian ministry of health built many APIs to serve different services such as E-referral with Avicenna, Covide-19 vaccine portal (vaccine.moh.ps) with Ministry of Interior to validate identifications and passport numbers, Covid-19 result portal (result.moh.ps) with both ministry of interior and ministry of education.

In addition, the ministry linked the Jordanian vaccine portal with the Palestinian on to track-vaccinated people. The ministry will also use APIs to connect Road Traffic Accidents (RTA) with Palestinian police, vaccine portal with result portal, and Avicenna with school health application.

2.3.4 Digital Imaging and Communications in Medicine (DICOM)

A standard enables medical imaging and their linked information to communicate. It is used to store and transfer medical images allowing related hardware such as, scanners, printers, servers and other network devices, in addition to PACS regardless of vendors. It is used by wide range of hospitals (Wikipedia, 2021).

DICOM is a standard used worldwide mainly to manage and connect devices related to medical images and their information in order to guarantee applications' interoperability. it facilitates the production, storage, sharing, displaying, transmitting, querying, processing, retrieving, and printing of different medical images such as Magnetic Resonance Imaging (MRI), Computed Tomography (CT), and ultra-sound images, etc. (Searchhealthit, Techtarget 2018).

DICOM as stated by the company itself covers radiology, cardiology, dentistry, and ophthalmology imaging, also known as, "ISO 12052 as classified by International Organization for Standardization (ISO)".

2.4 Data Availability

Data availability means that data is accessible and available to authorized users or stakeholders when they need it. Without data policy and decision makers will not plan for future improvements of the quality of health services presented to people in a proper way, as many says data is the current oil.

Electronic systems and emerging technologies play very important role in producing health data and making it available for individuals, healthcare providers, decision and policy makers in order to enhance the quality of care and improve population health. These technologies include but not limited to internet of medical things, Blockchain, cloud computing, decision support systems, and wearable devices. The current amount of data produced from such technologies is very huge and therefore needs to be govern and managed in a good way. Devices, networks and data have to be protected from any. Twenty eight percent of the Chinese population are linked to healthcare devices, 92 outsider's percent of healthcare suppliers' worldwide advocate for the use of electronic technology in health. Nighty four percent of United States hospitals are in the process of having electronic health records (PolicyAdvice, 2021). These numbers indicate that health generated data should be available regardless of vendors, location, and time of access.

This put tremendous pressure on healthcare providers and organization to ensure the availability of health data to different stakeholders, which will change the whole process of patients' treatment and foster them to re-engineer the way of providing healthcare.

2.4.1 Open Data

Another important concept related to data availability is open data, which means making the data available to anyone freely without any restrictions to access, utilize, and exchange. Open data can highly benefit researcher so they can share their findings with public health policy key persons and with decision makers to improve the quality of health services provided to people.

Effects on the implementation of openness data in health settings raise the need to balance between security and privacy and advantages of enhancing science research and provision of health. One of the solutions to protect issues related to security and privacy is to deidentify and anonymize any patients' recognizing information (Kobayashi et al., 2018).

Pandemics spread Zika, Ebola, currently Covid-19 put tremendous pressure on governments to adopt tools or build a framework to guide, and governance the process of collecting data related to public health. Public data linked to health must grant access to decision and policy makers especially in crises in order to take actions at the right time

(D'Agostino et al., 2018).

The balance between accessibility and security of data has been a debate for a long time; it is very important to make data available for those who need it and at the same time secure and control the use of it.

2.5 Data Compliance

Protecting data in general and healthcare data in particular is a big challenge and needs to handle it in a good way and according to the regulations and rules of each country

that govern the collection, use, storage, and data exchange. Countries should have the necessary measures to guarantee the safety and privacy of data mainly when sharing with others.

Data compliance components are:

- **Privacy:** it involves that individuals related data; mainly health information is protected from unauthorized access or disclosure, maintained by consents for the collection and usage, and have the security measures in place to achieve it. Privacy could be defined as a group of regulations pertaining data exchange and flow that should not be violated, such as who has the permission to access data, which data is retrieved, what is the aim of getting the data, and how many times the data is accessed?

  In order to protect privacy of patients, there is a need to adopt different technical methods. These methods include rules for exchanging, de-recognizing, recording in a secure way, transferring and managing protected health information. It also involves building regulations to monitor privacy breaches, and taking actions any time they happen (Price & Cohen, 2019).

  When dealing with big data there is always a concern about violation of privacy that may happen when collecting or using data, but eliminating risks of privacy has cost that needs to keep in mind (Price & Cohen, 2019).

  In the year 1948, "United Nations General Assembly" declared privacy as a core human right in its "Universal Declaration of Human Rights".

- **Security:** it involves implementing technical, administrative, and physical safeguards in order to protect confidentiality, integrity, and availability of data. Security methods are classified into three components: administrative measures security such as managing

the risk and evaluating the overall of the system related security issues, physical security such as securing data center and all its items, access-control and security of computers and servers. In addition to security measures with technical nature such as encryption of data, firewalls and data audit(Oh et al., 2021).

Emerging technologies such as Blockchain technology allows data exchange in a decentralization and transaction manner while maintaining the security of information being shared (Dagher et al., 2018).

- **Data Integrity:** it includes ensuring data quality, which means data is accurate, complete and reliable and must have the necessary policies and procedures to make sure that data is entered correctly, up-to-date, and stored securely.

  The challenges of achieving data integrity in Health Information Systems (HISs) summarized as errors related to human or machines, environmental concerns, policy measures, healthcare workers, and limited awareness (Thulare et al., 2020). In order to assess the inequalities of health in European countries at the regional level, reliable, comparable, and complete data must be available for the respective relevant indicators (Costa et al., 2019).

- **Compliance Monitoring:** auditing and monitoring of compliance in regular bases to ensure it complies with the regulation and rules that govern data collection, use, storage, and sharing. It involves the continuous reviewing of policies and procedures in addition to risk assessment conducting and ensuring that the employees are trained on the requirements of compliance.

- **Breach Notifications**: it includes notifying employees in charge and the top-level management in any event of health data breach. There must be a clear plan to response for any data breach at time, it should have the necessary steps to be applied

in the event of a breach including informing the affected users and reporting immediately to those in charge.

Health Insurance Portability and Accountability Act (HIPAA) set five measures to ensure compliance with its standards when treats digital medical information. These principles are assessment of risk linked to medical practices, be ready for disasters before it happens, conduct a continuous training for users, any purchased products should be compatible with security measures, and coordination should be made with departments before any change (HIPAA, 2013).

To govern the process of accessing data in order to maintain privacy, countries need ethics and regulations. In United States, the process regulated by the privacy rule built by

"HIPAA" which govern "Protected Health Information (PHI)". The rule as illustrated in figure 2 below consists of two approaches: expert determination and safe harbor. In the first approach, an experienced person de-recognized protected health information utilizing scientific methods to reduce the risk of identification to its minimum. It involves adopting such scientific methods to figure out the risk of re-identification even after removing all identifiers, Whereas the second approach eliminates eighteen kinds of identifiers such as mobile number, e-mail, patient file number, etc. which guarantee no recognition of identification (Kayaalp, 2018).

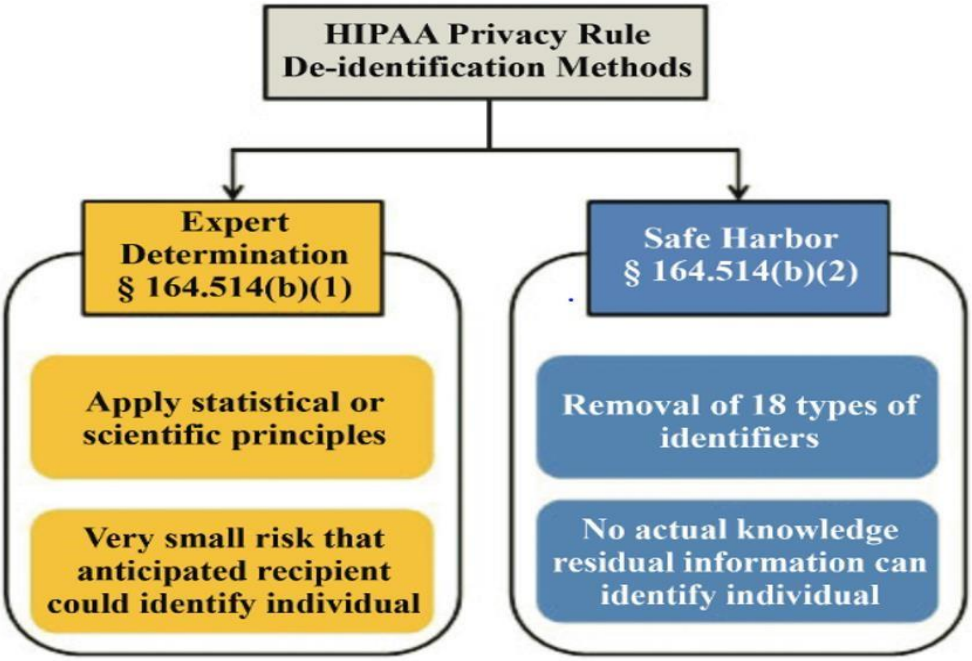

Figure 2.2: HIPAA Privacy Rule de-Identification Methods, source: (Kayaalp, 2018)

2.6 Interoperability

2.6.1 Interoperability Definitions

Institute of Electrical and Electronics Engineers (IEEE) standard computer dictionary, 1990 defines interoperability as the "Ability of two or more systems or components to exchange information and to use the information that has been exchanged ".

HL7 add to the previous definition the two terms functional and semantic, which translate to exchange information accurately without mistakes and the capacity to interpret the shared information and the effective use of it. Methods of standers such as HL7, DICOM mentioned earlier can play a primary task in achieving semantic interoperability by facilitating the exchange of information.

Office of the National Coordinator for Health Information Technology defines interoperability as "All individuals, their families, and their health care providers have appropriate access to health information that facilitates informed decision-making,

supports coordinated health management, allows patients to be active partners in their health and care, and improves the overall health of our population".

Healthcare Information and Management Systems Society (HIMSS) clarifies the term interoperability as "The ability of health information systems to work together within and across organizational boundaries to advance the effective delivery of healthcare for individuals and communities at three levels: foundational, structural, and semantic". **Foundational Interoperability:** data exchanged by one system to another without the need for interpretation by the receiving system. This level also known as syntactic or technical.

- **Structural Interoperability:** sets the format of data sharing among systems, it clearly clarifies the data sharing syntax.
- **Semantic Interoperability:** two systems exchange data and use it effectively since the second system interpret the receiving data, common terminology between the two systems.

The semantic interoperability plays a significant role in achieving common language and unified concepts among the different electronic systems making sure that all the used vocabularies are well understood.

The following approaches are identified to solve semantic interoperability issue:

HL7 standard manages the type of data used and its structure, the different versions of such standard vacillate the exchange of different operations such as admissions, discharges, and results.

DICOM standard manages the processes of storing, sharing, and transmitting various medical images by defining the format of them to ease their exchange among the

different electronic systems. HL7 and DICOM standards HL7 explained in details previously in this chapter.

Medical terminology classifications such as ICDs (ICD9, ICD10 and other versions) are standards that manage diseases, various health conditions, and medical procedures whereas LOINC standard used for managing various laboratory tests and measurements of clinical data.

Ontologies such as the government ontology defined by the Palestinian government Zinnar interoperability framework can contribute to addressing semantic interoperability; it defines clear, accurate common understanding of the various concepts utilized in the ministries that represent the government of Palestine. Zinnar handles the meaning, structure, vocabulary, codes, and various business rules needed to ease exchange of data as explained clearly in different sections of this study.

APIs also help in solving the issue of semantic interoperability among various data sources by providing a unified interface for applications and developers to access the needed data, they are used as a method as a method to facilitate communications between different databases or data sources. APIs built based on data dictionaries, data format, data structure, and common data models which provide a standardized and structured approach of displaying or representing health data.

All definitions highlight data sharing and using between different information and communication systems and how the communication among them can be done securely or in a channel that maintain the privacy and confidentiality of sharing data regardless vendors or applications using different data exchange protocols. Data standardization is the primary key factor for having interoperability among health

system. Interoperability assures that information shared and distributed at various levels.

2.6.2 Interoperability Challenges and Barriers

The following summarizes interoperability challenges and barriers:

- **Technical Challenges:** they are challenges pertained to technical issues such as data standards, formats, and protocols utilized by various systems in addition to privacy and security measures that are significant to protect health data. In healthcare settings, standards such as HL7 and DICOM contribute to solving such challenges. These challenges also known as foundational or syntactic challenges.
- **Semantic Challenges:** they refer to varies in the interpretation and meaning of data that could come out with misunderstandings and errors.
- **Organizational Challenges:** they are challenges related to differences between different organizations regarding workflows, policies, regulations, procedures, and funding.

In Kenya, a framework was proposed to overcome the factors affected the implementation of interoperable various electronic governmental information applications in order to deliver services to citizen in an efficient and effective way. The factors identified for adoption of such a framework to ensure interoperability, classified to seven items: Adoption of standards to allow sharing of data, security of data either stored or shared, as well as security pertained to infrastructure to ensure availability, confidentiality and integrity of data. In addition to ensuring quality dimensions of data such as accuracy, completeness, usability and consistency through a well stablished infrastructure, performance issues related to productivity and time responsiveness,

accountability of maintenance and protection used by different users is the responsibility of individuals and organization. Finally, take in consideration the compatibility factor of different hardware and software for successful implementation of interoperability framework. Technical, semantic, and organizational interoperability types have to be understood and solved when providing public services by the different electronic systems (Ronoh et al., 2018). The amount of data generated increased dramatically the last decade, but most of the data produced worldwide is inaccessible to public for different reasons such as legal and privacy concerns, or issues related to security at the national level (Verhulst et al., 2014). One of the challenges in European Union (EU) countries is people traffic across different countries of EU, which makes healthcare interoperability a big issue, in addition to different tongue. Flow of health data must occur according to the demands of interoperability, security, and legal aspects imposed by "European Patients Smart Open Service" rules (Gavrilov et al., 2020).

High cost of interoperability implementation, absence or lack of regulations, and lack of standardization mainly in developing countries are among the main barriers. The heterogeneity of different applications, databases, and systems used by various healthcare organizations and vendors and the absence of their cooperation and coordination as well as the differences of data formats, coding, or terminology being adopted.

High cost implies the needed investments in infrastructure, upgrading applications or systems, and capacity building to gain the necessary expertise. Absence of legal framework, lack of governing structures and related policies and procedures as well as the existence of close systems related to a specific vendor will all reduce the possibility of successfully implementation of interoperability in healthcare.

Another factor that should take in consideration is the cultural factor such as the degree of belief about the importance of data sharing, attitudes, trust and resistance to change.

There are many technical barriers of sharing data with electronic health records:

- Lack of standardization of information and various data quality.
- Mismatch between patients and providers among different organizations.
- Financial obstacles such as the high costs needed to improve, adopt, and support electronic health records in order to comply with the dynamic change of needs in health domains (Kelly et al., 2020).

2.6.3 Interoperability Methods and Approaches

There are different methods and approaches worldwide to solve interoperability in healthcare domain since it increases cooperation among different healthcare providers, it improves quality of care and safety of patients, enables researchers to find gaps, and therefore better management, decision-making, and good health outcome.

Web APIs and technologies of Semantic Web have the possible to deal with the challenges of healthcare information integration among different heterogeneous systems as well as the usage of such large volume of integrated information collected from various sources as illustrated by (Peng & Bai, 2020).

Methods regarding integration of healthcare data, classified into three parts:

APIs with manual alignment: this method based on aggregating healthcare data from various sources through utilizing APIs first and making manual alignment second in order to allow the integration of the data that has various data models. Semantic Web: this method or approach utilize technologies of Semantic Web in order to allow the integration of healthcare data collected from various sources ambiguity of data

interpretation. Platform: this method categorized as a Platform if it acts as a platform, which means it has different links, data storage and analysis of its own. In addition, to Data Warehouse approach as a fourth type of integration but excluded from the classification since the related studies in the review mentioned it as a location of data storage without a concept of integration(Peng & Bai, 2020).

A middleware approach to solve interoperability in healthcare settings based on a software library in order to connect a group of sensors utilizing both proprietary and standards protocols with the goal to reach any data. The proposed middleware, assumed to be utilized by third-party software programmers, providers and applications of health services in order to capture patients' data allowing them to guarantee interoperability with a large number of healthcare sensors with lowest effort. Developers utilizing such software library do not have to perform each protocol separately and can concentrate on processing and analyzing data (Georgi et al., 2018).

Following up and observation of human diseases in term of prescribed medications in healthcare settings are the factors that focused on to build IoT-SIM (Internet of Things Semantic Interoperability Model). It has three components: User Interface, Semantic Interoperability, and Cloud Services. Through User Interface, physicians and patient communicate together with using IoT devices. A physician can monitor and prescribe his or her patient remotely regardless of location and time or any kind of restriction of selected suppliers' device. The role of Semantic Interoperability is to interact directly with a User Interface in a meaningful manner. Semantic Interoperability is utilized to confirm that IoT devices from various suppliers are interoperable with each other. IoT devices capture data from UI and add the needed semantic to remove any ambiguity and

then comes the role of data analytics to draw patterns and knowledge (S. Jabbar et al., 2017).

An architecture based on an infrastructure of a cloud and depended on Service Oriented Architecture (SOA) model proposed to ensure three types of interoperability: semantic, technical, and process in addition to maintain security (Gazzarata et al., 2015) as shown in figure 3 below:

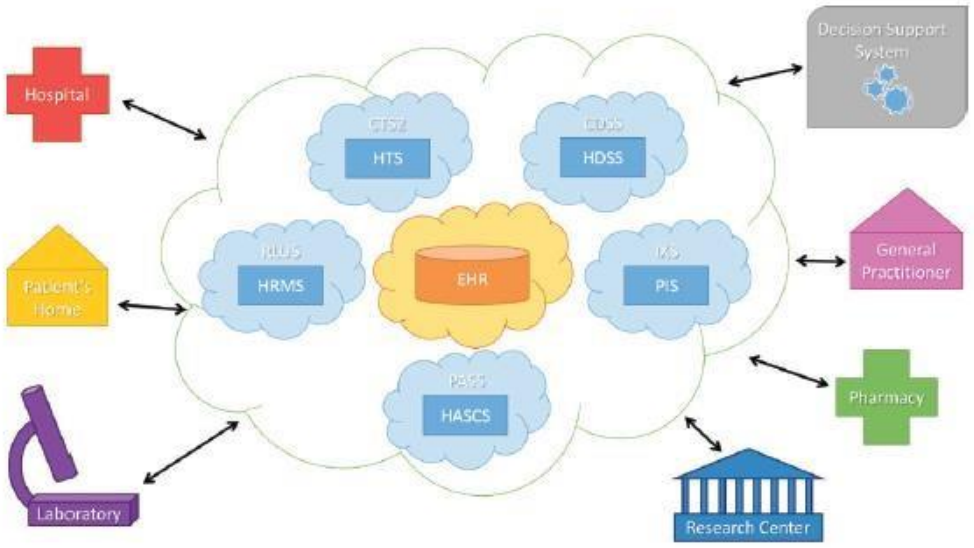

Figure 2.3: The Architecture Model (Gazzarata et al., 2015)

The proposed solution allows all players who have the role of the treatment process of patients to access the Electronic Health Record stored in a public cloud and secured by means of data encryption to prevent any unauthorized access. The model utilized different standards to facilitate the exchange of information such as SOAP and Health Level 7 version 3 (V3) in addition to (HSSP), The Healthcare Services Specification Project to provide the standards needed for SOA to allow sharing data among different systems. The standardized services supplied by HSSP, divided into three parts: services that have the nature of technical or infrastructure such as exception handling and

security control, services that are pertained to business like terminology, and health related services as clinical decision support. All services should comply with standards provided by HSSP. Common Terminology Service Release 2 (CTS2) as shown in the above figure for example is a standard to give coherent characteristics to build interfaces of services in order to search, manage, and have access to content of terminology such as (HTS), Health

Terminology Services (Gazzarata et al., 2015).

Another interoperability framework based on SOA as a mechanism to provide services to users in Indonesia through web services interfaces to share data among different databases in which various stakeholders can build their own applications. The E-health system can get the data supplied from the different service modules such as laboratory, radiology, and pharmacy systems. The proposed framework connects to a predetermined RESTful web service that builds a dataset, which can be accessed after the authentication is validated. The data generated by the web service can be called by providing the service number and has a JSON format, figure 4 shows the interoperability scenario of the Ehealth system (Amin et al., 2020).

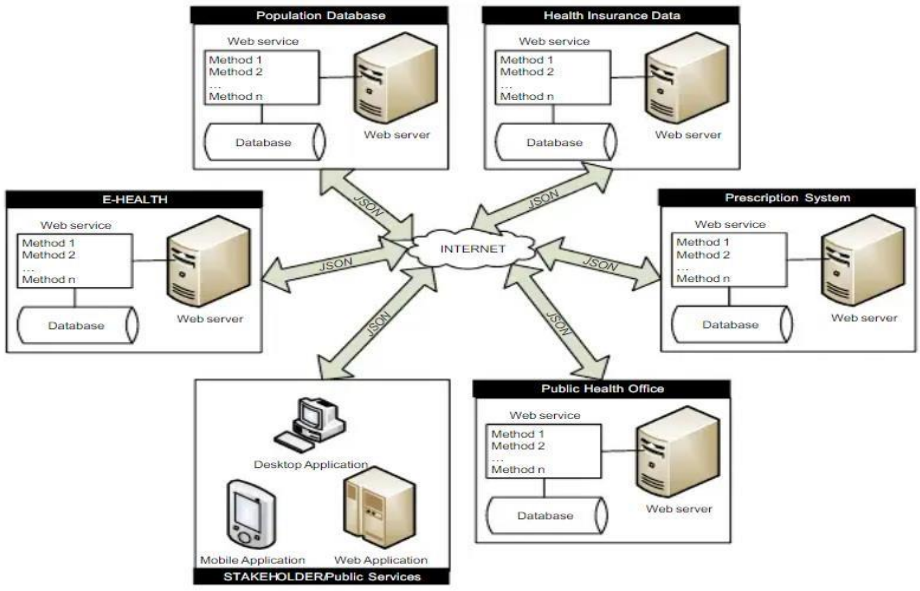

Figure 2.4: Interoperability of E-Health System(Amin et al., 2020)

A framework of unified semantic interoperability depended on fuzzy ontology for dispersed Electronic Health Records, proposed to solve the problem of semantic interoperability. The framework consists of three layers: the first layer records heterogeneous data sources such as Archetype Definition Language (ADL). The various entries from data sources, converted into crisp ontology with a proper for each dedicated type. The second layer maps local ontologies with a global reference crisp ontology that describes all data by combining and integrating all local ontologies and after that crisp ontology is transformed to a standard fuzzy ontology, and the user interface layer makes sure that any semantic related queries can be executed according to the reference unified fuzzy ontology. As shown in figure 5 below each source of data mapped into local ontology. The framework assumes that widening a crisp ontology to fuzzy one will enhance data integrity and provide a global electronic health record interoperable ecology. ADL provides specific definition of medical terminology (Adel et al., 2020).

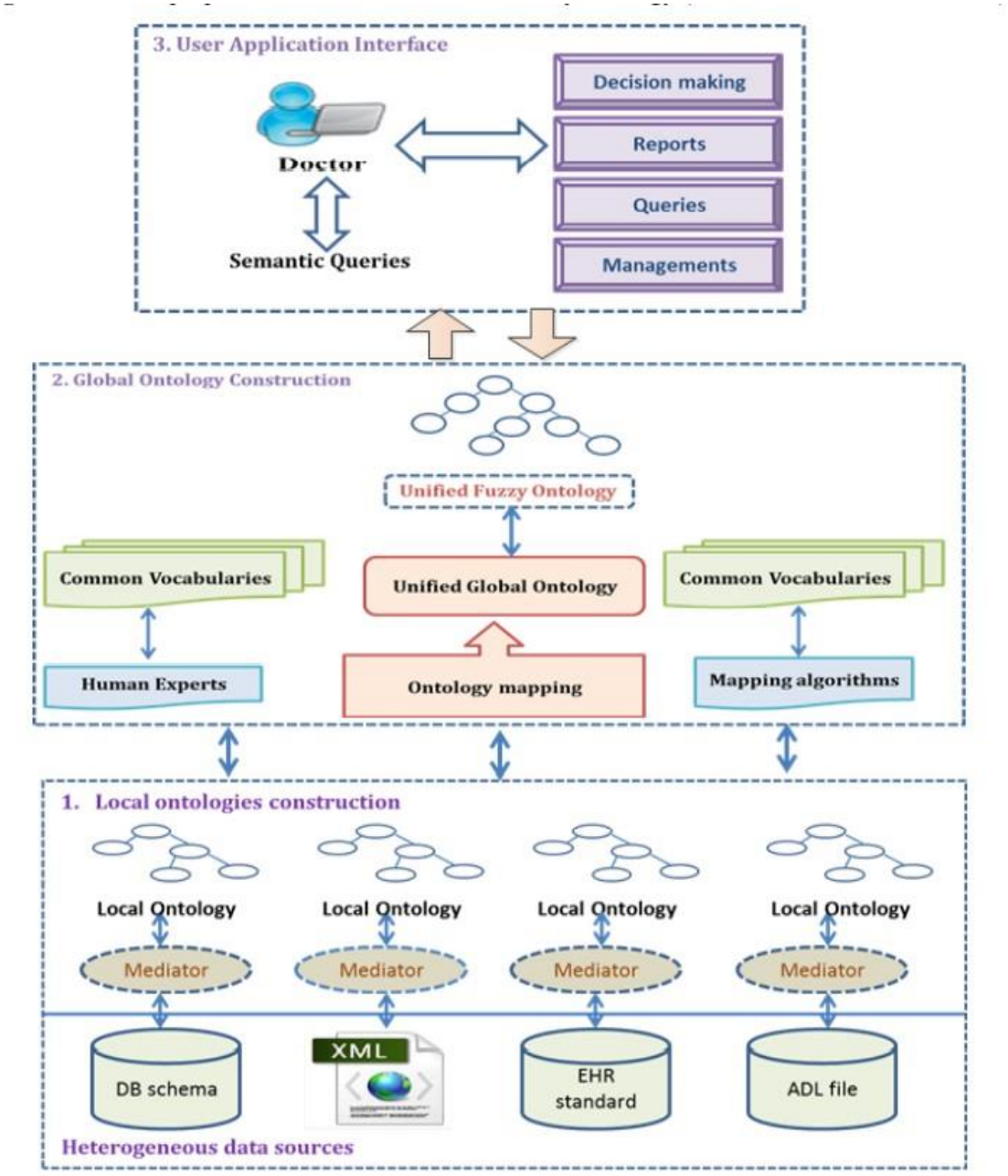

Figure 2.5: Semantic Interoperability Framework Based on Fuzzy Ontology (Adel et al., 2020)

In order to enable data subjects, who are the owners of the personal information to administer and download such information related to health through a proposed platform known as “MyHealthData”. The mentioned platform has three components:

mobile application for users, API for sharing and transforming data located in Health Information

System (HIS), and a relay server act as a mediator that linked to the Blockchain technology to guarantee integrity. The study gave many services to users, through the proposed platform such as enquiry about medical check-up information. The relay server manages orders and replies shared between mobile application and other facilities (hospitals and clinics) in addition to a third-party institution connecting them to the Blockchain (Panacea; public Blockchain for medical purposes to ensure data reliability depended on software development kit, SDK). The API provides the needed functions so that users can access the requested medical information recorded in HIS by using the mobile application, then the requested data transformed into JavaScript Object Notification (JSON) to comply with HL7 and FHIR interoperability standards. Data encryption was used to ensure security of data sharing over the network. Figure 6 illustrates the architecture of the proposed platform (Bae et al., 2021).

Figure 2.6: My Health Data Platform (Bae et al., 2021)

In India, a model based on Electronic Health System was proposed to link all the users of HIS into one centralized location in order to store and exchange patients 'data collected from the electronic health record system as shown in figure 7. The proposed solution depended on a cloud approach that allows all healthcare providers to access the data on the EHR system and utilizes the resources of the cloud at the different levels of healthcare provided by the country. All the collected health information from various sources handled and recorded in a worldwide cloud database. Through this model, health workers could reach patients' information collected from different sources whether they were administrative (demographic information) or medical (clinical documentation for example) in a secure way using an EHR web application. The provided solution uses a patient identification or any other viable document, which is used to create a unique identification number of the patient. The mentioned solution uses a cluster cloud called

"MongoDB Atlas Cloud Cluster "that collects different types of information and has various sets in order to represent a cluster in the utilized cloud then the extracted data processed by the provided algorithms and disseminated to the intended end users (data retrieval). For recording, collected information from users' entries is restored using web application that could run from different devices linked to the internet and then managed to achieve the requested standards before saving to the cluster. The cloud-based solution enables authorized users to access data any time from any location in the world (Pai et al., 2021).

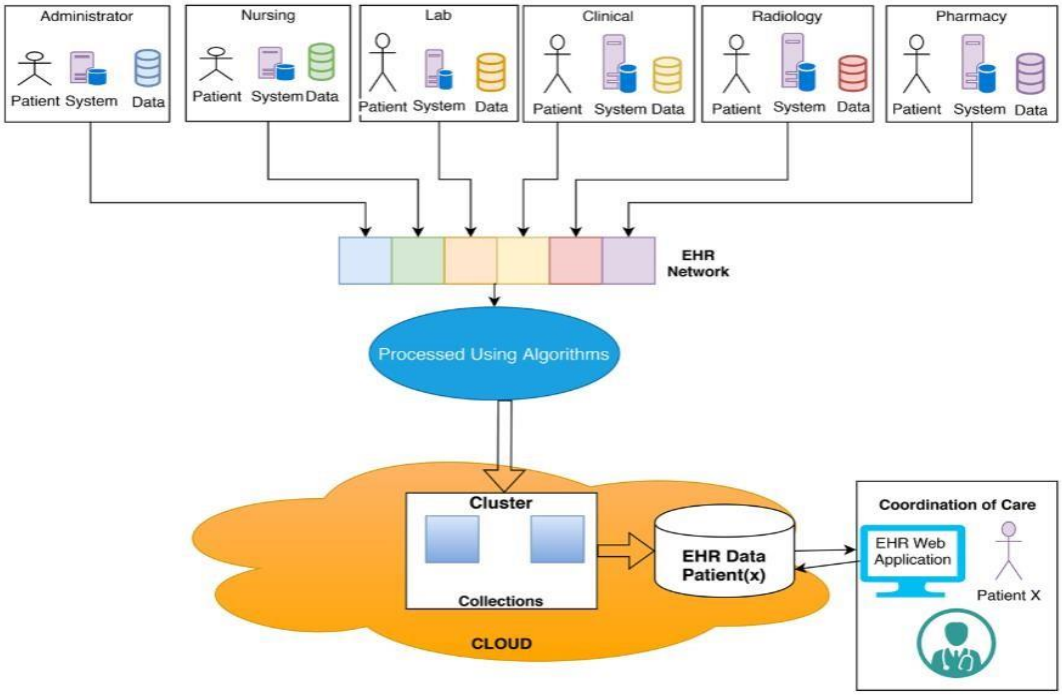

Figure 2.7: EHR Model for the Coordination of Care(Pai et al., 2021)

A framework based on Blockchain technology called BiiMED for improving interoperability of data as well as integrity when exchanging in electronic health records.

The mentioned model has an "Access Management System" for the sharing of electronic health records among various healthcare providers and a "decentralized Trusted Third-

Party Auditor (TTPA)" in order to guarantee the integrity of data. The model combines both HIS that uses different standards such ICD10 and DICOM with Blockchain. The used HIS framework consists of a front-end layer that accommodates a set of web portals for suppliers of healthcare such as admin and medical staff portals and back end layer. The back-end layer provides a solution based on the cloud contains web services for data sharing in addition to database server, and a medical record server for recording BLOB; Binary Large Objects as Radio and CT images. BiiMED Blockchain that was

created using Ethereum platform has the role of managing and validating the exchanged information among various healthcare utilities. BiiMED has ten nodes (Ethereum) two of them used for data mining in Amazon servers as illustrated in figure 8. The access management system has two modules: user management, which has a contract about the management of the medical entity that enables the addition, or amendment of new facilities. In addition to exchange management accommodates two contracts one for the management of Medical Facility Access responsible for retrieving data pertained to a patient from data exchanged and the other one for the management of the Trusted Third Party Auditor Access to validate the exchanged data by granting access to the medical entity system (R. Jabbar et al., 2020).

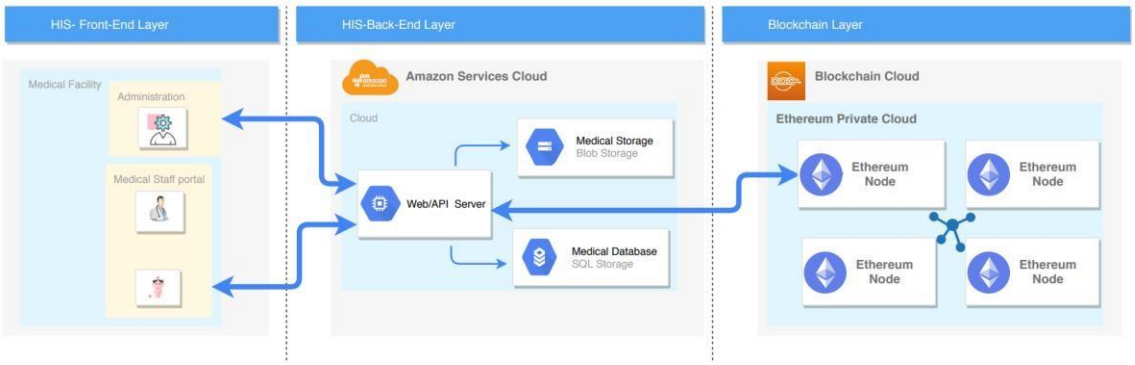

Figure 2.8: The Architecture of HIS and BiiMED Solution (R. Jabbar et al., 2020)

In Rwanda 2013, a middleware known as Health Information Mediator (HIM), proposed to solve the problem of interoperability between various systems and shared services based on ESB; Enterprise Service Bus, which is a platform that provides a centralized bus to administer all connections between different components. These components depended on a loose coupling concept that allows them to function in an independent way so if one component fails it will not affect the other. The proposed model consisted of three layers: interface, persistence, and mediation as shown in figure 9 below.

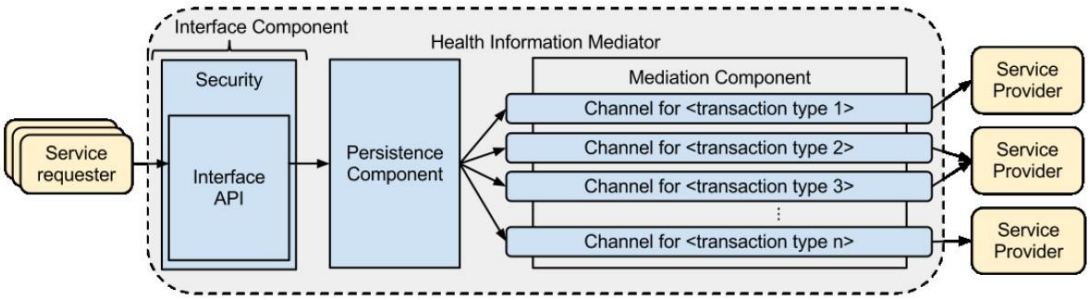

Figure 2.9: Components of the HIM Architecture (Crichton et al., 2013)

The interface layer uses an API that enables various application to ask for a service via health information exchange. It defines and manages all the requested incoming services received by a standardized protocol such as HTTP and then converted into a standard format, reachable by the various parts in the layer such as java objects. It also ensures security and imposes accessibility policy. The persistence layer handles the received requested services, sent by the interface layer and observes a transaction needed to finish the received request. It records received transactions, keeps a copy of them, and sustains a permanent data place for each transaction's request, response and metadata for the purpose of auditing and logging, in addition to identifying and solving problems by the system administrators. Finally, the mediation layer is the body responsible for the execution of transactions as well as synchronization and interpreting of different messages. It has a set of channels pertained to transactions, a channel is supplied for each type of transaction such as save a visit of a patient. All data mapping happens in this layer to make sure that the received data complies with the internal format (Crichton et al., 2013).

To solve interoperability of socialized healthcare (a part of digital health based on real time connections among different stakeholders) in Nigeria, a proposed architecture

framework based on the cloud in order to allow different services to be shared. The framework enables patients to consult accredited physicians regardless of their locations. Patients can decide by his or her own which doctor to consult with using any web tool linked to a centralized server located in the associated cloud. Patients can connect to upto-date and correct healthcare data using any internet-enabled medium device such as smart phones, personal computers, and tablets. The proposed approach utilizes a web or a cloud server that supplies services as requested to users from a dedicated data pool in a timely manner (Ayeni et al., 2018).

A framework of electronic health utilizing distribution memory approach and mechanisms to process heterogeneous data using loose-coupling technology was proposed as a solution to the interoperability issue in the developing countries. The distributed electronic health model based on standards of HL7, to allow interoperability between different healthcare information applications. The framework utilizes MPI, the Message Passing Interface in order to conduct backups of health information on regular basis. A remote server using technology of loosely coupling can access the distributed database. The framework also has features of data recovery and can treat large data via a distributed ecology that allows for distributing data and store it across different servers. The proposed model can present a cheap service to low income countries in an effective way. The system has many modules such as login modules for both the clients and the physicians, EHR server, and HL7. The module of a client will consider as the remote healthcare station for the patients living in rural areas and equipped with the needed items. A patient from a rural area will visit such station to get electronic services. The administrator of the station enters history of the visited patient to the system of the healthcare for the sake of registration and provision of services. Each sub system of the

electronic healthcare system has a module pertained to EHR to record data using identification number of patients ensuring that data can be utilized for services of distributed electronic health record. Generally, the patient registration occurs at a local server according to the proposed model. If he or she changes the location and wants to receive a service, they can get it from the local server of the new place then data is transferred to the main server. All the data of the healthcare electronic system must comply with HL7 standards (Rinty et al., 2022).

In a study titled “towards nationwide electronic health record system in Jordan” showed that the lack of suitable middleware and heterogeneity made electronic records inaccessible nationwide although the country has a good and reliable telecommunication infrastructure. The researchers recommended implementing an approach that adopt an architecture of middleware software for better information access. The proposed technique would solve the problem of interoperability and give health providers the opportunity to exchange health information with patients on time and when needed (AlZghoul et al., 2016).

A proposed framework known as “Medical Data Interoperability through Collaboration of healthcare devices” (MeDIC) which, optimizes over an internet of medical things devices cloud based by adopting translation at the network edge through utilizing two agents propping and translation. The probing one keeps a list of MeDIC related devices inside a local network and allows one of the MeDIC devices to demand conversion of data from another device when the requesting device does not have the capability to do the conversion itself. On the other hand, the translating agent of the subsequent device transforms the data into the needed format and sends it back to the requesting device.

Such agents allow devices of internet of medical things to share their excessive computed resources for translations of data for the sake of minimizing accesses of the cloud. In this model, devices classified as legacy are endorsed through fog resource managers and MeDIC enabled. Figure 10 showed the proposed framework. MeDIC devices have interfaces of probe and translation that enable the exchange of resources via services of data translation. Source devices (legacy devices) have sensors that create patients' medical information; these devices create data according to the format of their vendors. Whereas sink devices involve analytic, monitor, and adapter devices that join to the patients' medical information (Jaleel et al., 2020).

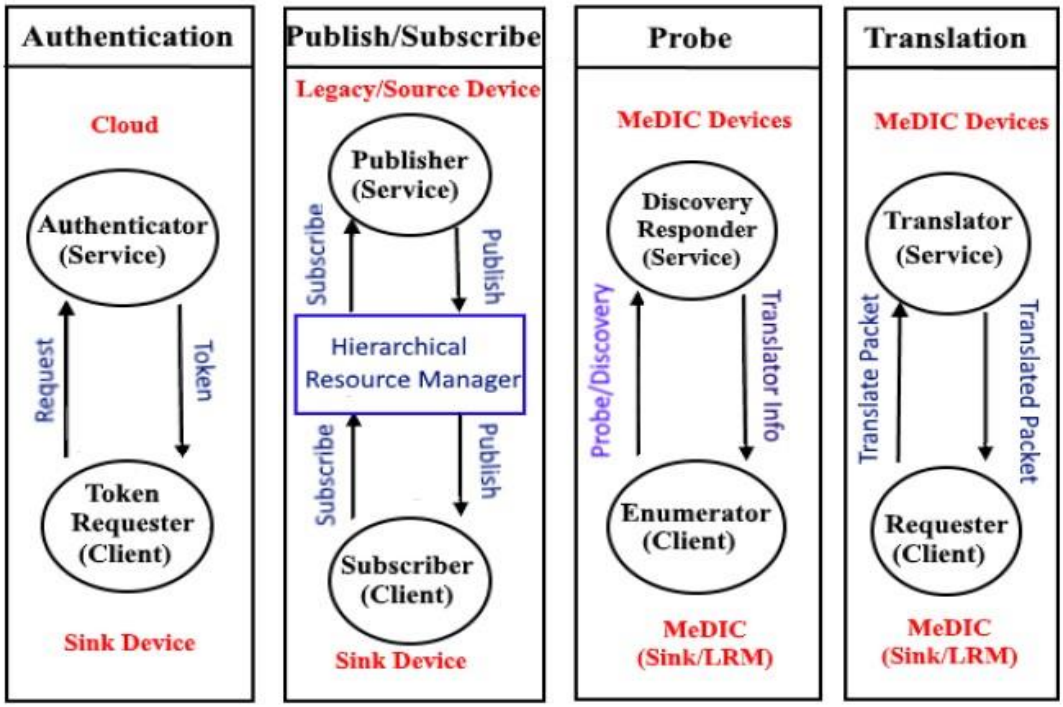

Figure 2.10: MeDIC Proposed Framework (Jaleel et al., 2020)

In addition to that, they also include physicians' and patients' other devices such as wallets that have data process capabilities. Sink devices can convert medical data from one format to another via their interfaces of translation so they are classified as edge

devices. Resource manager constitutes hierarchical way with CRM; Cloud Resource Manager at the top of this hierarchy, ERM; the Edge Resource Manager at the middle, and LRM; Local Resource Manager at the level of the local area network. ERM and LRM are classified as fog resource managers since they cache the pertained parts of the related resource tables from the cloud resource manager. The authentication interface helps sink devices to have access to source devices by utilizing a dedicated server for the authentication process on the cloud that keeps a set of patients' devices with their credentials and permissions called RTAB; Resource Table. A patient's device approved and indexed with its related URL; Uniform Resource Identifier. After the authentication is granted to devices, they can upload their own data and download data from other devices in their original format via CRM. The authentication interface has TokenRequestClient and authenticator agents; the first one executes in sink devices when they want to have connection with source devices by having a key that granted the access to the source devices as input. It then dispatches a demand to the authenticator at the cloud or at Local area network if the patient connects locally for URLs and tokens of internet of medical devices pertained to patient. The second agent executes through the cloud or at the local level and has the response to the request by creating the needed tokens of all patients' devices stored in the RTAB. The interface of subscriber or publish supplies a subscriber agent that executes in sink devices and helps them to get the needed medical information from source devices after the authentication approved. When a legacy device asks for a data demand via the subscriber agent, the resource manager gets the requested data from the publisher agent of the source device, translates it according to the format of the sink device, and sends it back to the subscriber agent. CRM delegated to translate medical data into the format of sink devices before sending

it. It supplies a fog service known as ERM or through an edge computer at the local network, whereas LRM supplies a reference data interoperability related to legacy devices that reduces traffic on the cloud. The probe agent keeps a TRT; Translation Resource Table that has a list of stored devices, fill and keep it updated through the probe Enumerator agent while the discovery responder agent performs the server side of the interface in MeDIC related devices (Jaleel et al., 2020).

There is a growing demand for a healthcare data system that is interoperable and can give every healthcare practitioner involved in the treatment process a shared common picture of a person's critical data, regardless of location or organization. A framework for describing the interoperable system's fundamental components: a portal based on the cloud, and a web service API for having access and managing exchanged information was proposed by (Azarm et al., 2017).

The framework has a minimum data set that consists of a profile pertained to the patient (demographic data), his or her medications, and a health profile. The proposed solution has a portal known as myPHR, a group of APIs (web services), and a system for storing data as shown in figure 11. Employees of the healthcare organization referred to as HCO in the figure below, other beneficiaries utilize API-enabled mobile apps produced by healthcare app developers. From patients to HCO staff, the architecture is built to serve a wide range of users. Patients and care providers can access and update data stored in myPHR. Hospitals, for example as HCO actors, typically have an EHR system in place that can utilize APIs to integrate the exchanged data to their electronic health system in addition to sending their information to myPHR. Doctors, labs, pharmacies, as well as physiotherapists and other health care givers (classified as small-scale caregivers) can also integrate their patients' data to the system; if not they can still have

the access to myPHR. The proposed solution must comply with a governing committee or body regulations and rules representing the overall health care system in order to maintain privacy(Azarm et al., 2017).

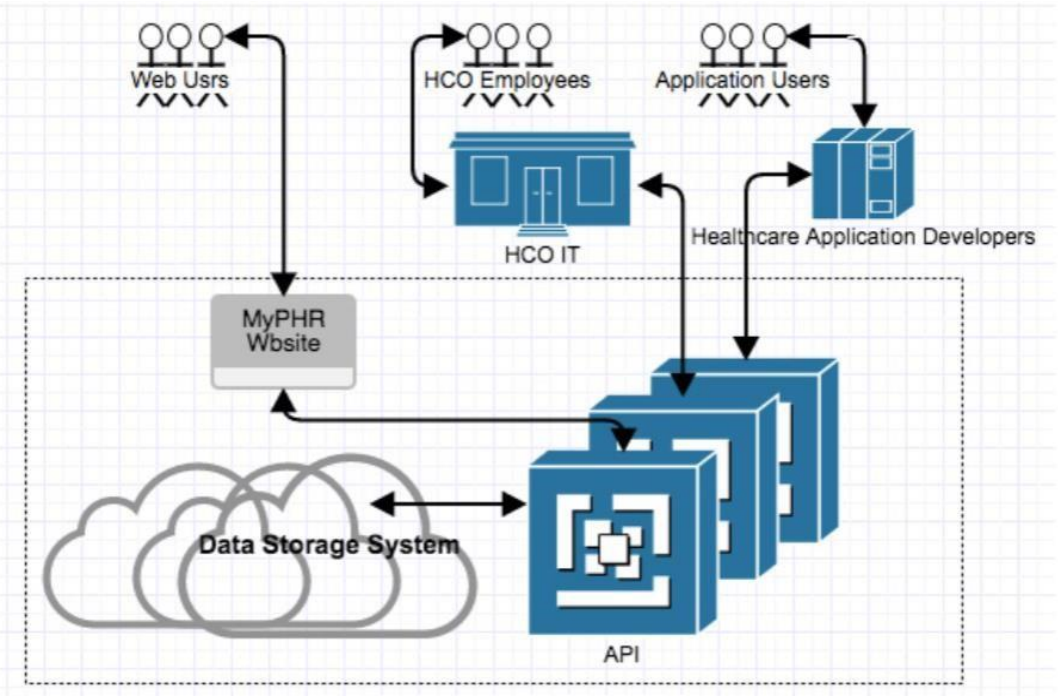

Figure 2.11: The Proposed Interoperable Model (Azarm et al., 2017)

There are different approaches for collecting data from various applications: at the simple form, it can be “extracted, transformed and then loaded into another application or system”, this approach known as “Extract, Transform and Load or ETL” as illustrated in figure 12 below:

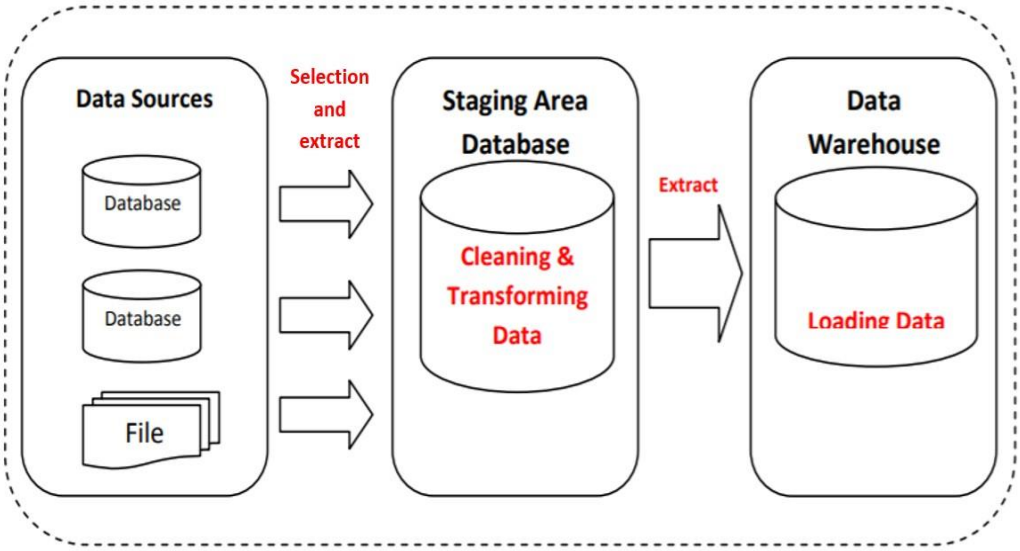

Figure 12.2: ETL Process (Mohammed & Talab, 2014)

The three operations: extract, transform, and load that carried out through the ETL process as described below:

Extract: Extracts information from different relational databases, including but not limited to SQL, My SQL, and Oracle. Transform: Data cleansing processes are performed after the data has been transformed. Load: The collected data are then loaded into the Data Warehouse after these two actions are completed. Data can also be collected from various flat files such as XML, CVS, and spreadsheets using ETL job and record it into data warehouse for extra visualization and more analysis (Vyas & Vaishnav, 2017).

There are two types of extraction: the first type known as the method of logical extraction, and the second one called the method of physical extraction. The method of logical extraction consists of three type: notification update: This is the simplest approach to retrieve the data if the source system sends us a message that a record has been modified and explains the changes. Incremental extract: Some applications could

not have the ability to notify users of changes, but they will be able to determine which records have been altered and offer an extract of those records. Full extract: Possibly, because some applications are unable to determine which information has been altered, a full extract is the only approach to extract the data from the system. To figure out what has changed, the entire extract relies on preserving a copy of the previous extract in the same format. The deletions are similarly handled by the full extract as well. There are two types of physical extraction method: Online extraction: Data is extracted directly from the source system using an online extraction method and Offline extraction: The data is expressly arranged outside of the original source system, rather than being pulled up or retrieved straight from it (Vyas & Vaishnav, 2017).

In the environment of Data Warehousing (DW), ETL operations are part of the integration layer, which tries to convert data from various sources to targets' format. ETL job is in charge of extracting data, cleaning it, matching it, and loading it into the destination system. There is a paid ETL job on the one side when utilizing a third party whereas there is a payless ETL job on the other side, for example, Microsoft and Oracle offer this job free of charge for every license of their database management system (Sajida et al., 2015). ETL job could also be used from the different available open sources over the internet.

Another approach to collect and transfer data is using Application Programming Interfaces (APIs) which are tools that serve two programs to communicate with each other; one application or program sends a request to another and returns the response back to the sender (Gliklich et al., 2019).

DW is a process of gathering data from different sources of data into one summary database that provides stakeholders or beneficiaries with a significant tool to manage

and analyse data efficiently using technologies such as Artificial Intelligence (AI) and data mining. DW is a powerful method that contributes a good solution for the issue of interoperability among different electronic systems regardless their structure or format.

Clinical data warehouse as indicated by (Mohammed & Talab, 2014) has many challenges such as format of clinical data, analysis and purpose of business, in addition to integration and quality of data as well as the process of ETL.

The architecture of healthcare warehouse at the national level could be as appear in figure 13 below:

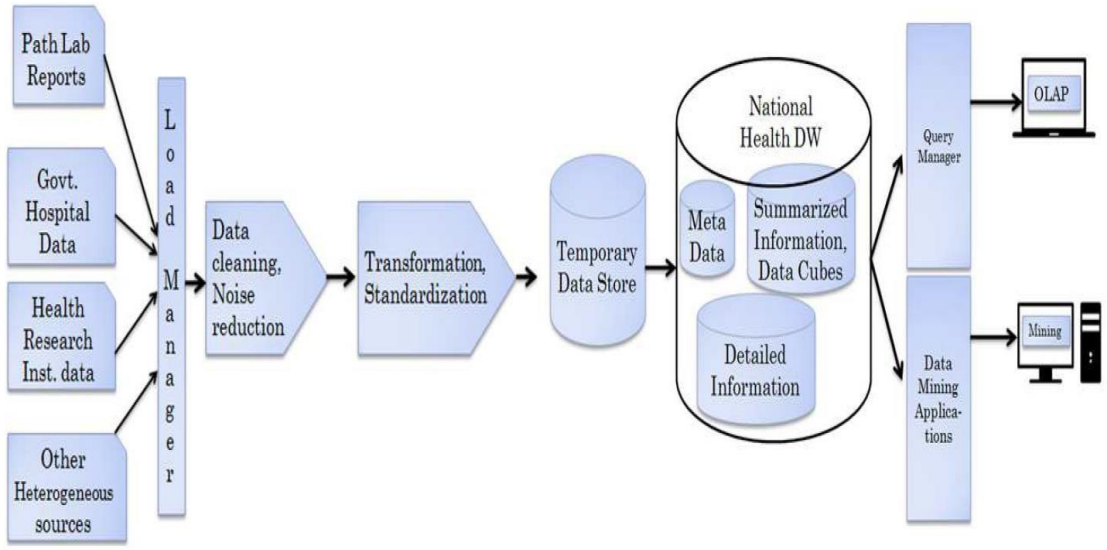

Figure 2.13: Architecture of Healthcare Data Warehouse (Khan & Hoque, 2016).

Information pertained to healthcare from various sources of both government and private like clinics, hospitals, diagnostic stations, and research institutes has to be gathered. Utilizing ETL job, data needs to integrate into an interim data storehouse, then data cleaning and normalization take place allowing getting it ready to be loaded into data warehouse. Many tools such as data mining and OLAP, Online Analytical Processing can be utilized over the data warehouse. In the development of this model, 4D healthcare data cubes adopted to fast queries, processes, and analysis as shown in

figure 14, incremental extraction was used to reduce storage requirements. The model structure followed star schema, as it is the most logical one implemented in data warehousing. Needed datasets built in order to be used by users such as number of patients grouped by gender, age, date, and diagnosis, procedures number distributed by date and provider (Khan & Hoque, 2016).

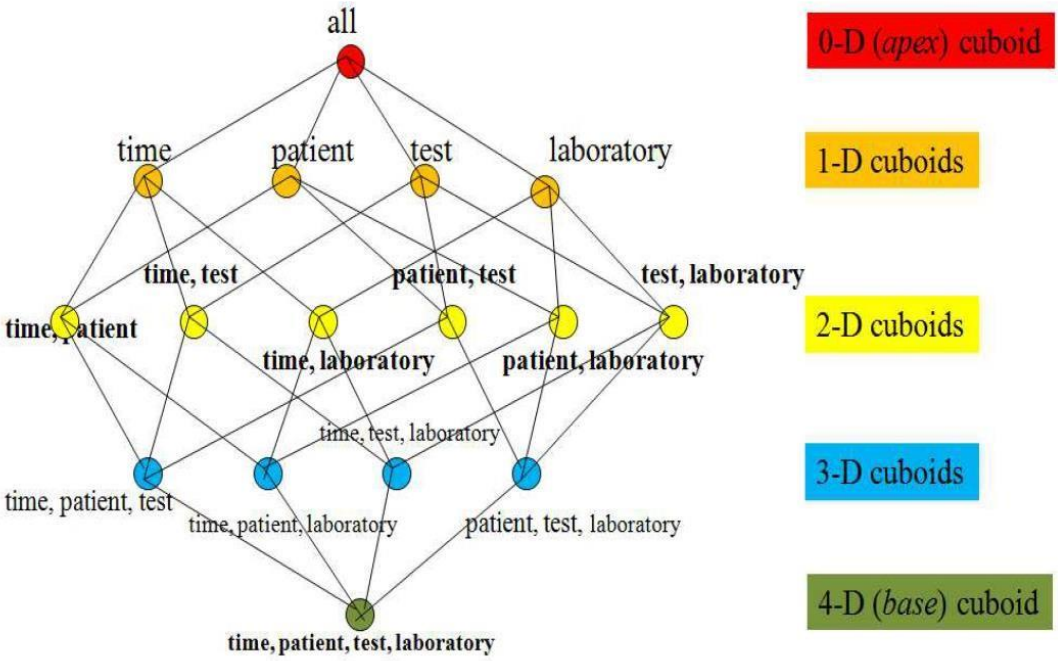

Figure 2.14: Health Data Cube, (Khan & Hoque, 2016)

Gavrilov et al. data warehouse depended on ETL process (integrates data collected into a common predefined schema using different available gadgets) proposed to provide a group of services in European countries to allow platforms of national electronic health building cross-border networks of healthcare information that complies with epSOS, “European Patients Smart Open Services”. The proposed model combines both organizational and technical interoperability types using HL7 standard and OpenNCP,

“Open National Contact Points” framework for the sake of supplying an architecture that

is modular, inter-operational, and scalable. In this paradigm of Extract, Transform, and Load, which utilizes web services standard and technologies of XML through SOAP or WSDL protocols (Gavrilov et al., 2020).

Data collected, transformed into a staging area before transferred to the data warehouse. This model identifies the shared healthcare data format of XML documents, which are drawn from Online Transaction Processing (OLTP) systems into the staging area then the loader of the web services, which is an application of a web service, gets the WSDL and creates SOAP messages to the web services that implements extraction and transformation of data. The data extracted and transformed from operational DBMS, Database Management System into format of XML (Gavrilov et al., 2020).

Structure Query Language (SQL) to XML transformation executes the extraction from the operational database into a middle XML format, which then transformed utilizing eXtensible Stylesheet Language Transformations (XSLT) into a document with XML formatting that matches the shared schema, which is tested via XML authentication engine. The loader of the web service located next to the staging area. It gets data from the web service and sends new one then after the XML instances with the new information are received it has to be recorded in the database of the staging area then it integrates with the warehouse data through the loader by sending a SOAP request to a web service (Gavrilov et al., 2020).

When data is complete (extracted according to the XML format) it transferred back to the loader via another SOAP message. The loader gets the XML document and sends it

to the staging database through the interface of the XML database programme, at this stage, the

XML file recorded in the object relational database physically as identified by the sharing schema. Now the data needs to be converted from its current object relational status or structure into the data marts using structure query language with references for more traditional structures in the data warehouse, see figure 15 (Gavrilov et al., 2020).

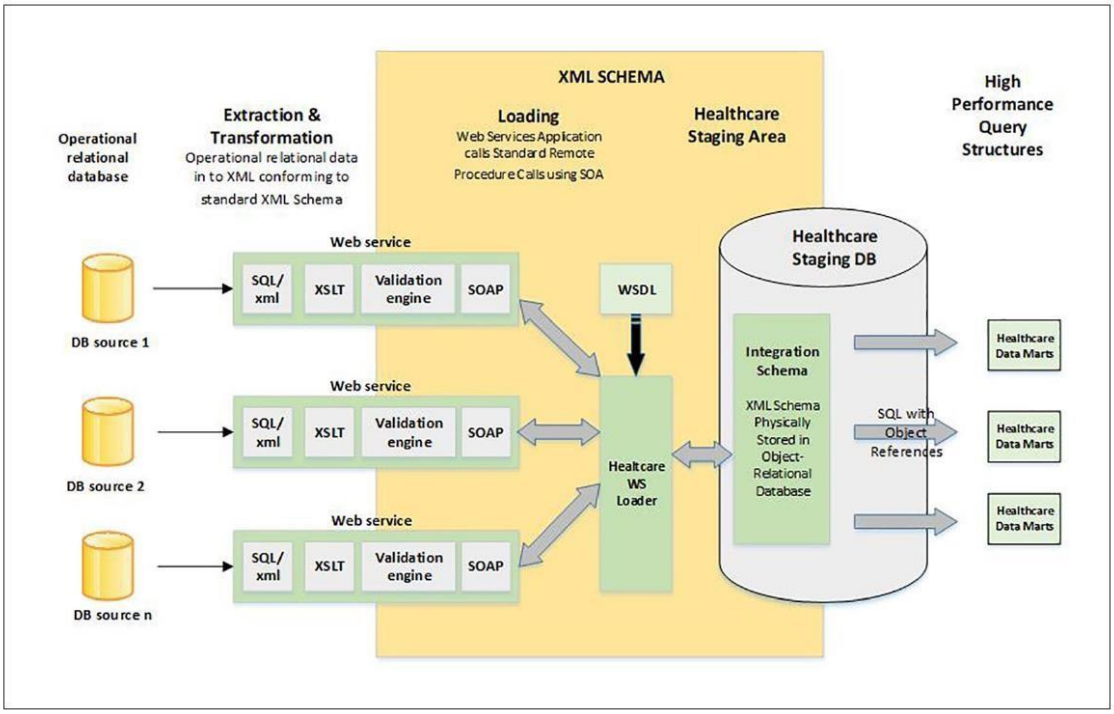

Figure 2.15: In the staging area, an XML schema and a Web services architecture were used to build a healthcare data warehouse based on a Web services architecture. (Gavrilov et al., 2020)

There are three types of interoperability according to (M Jarrar et al., 2011):

- Technical, focused on the availability of standards, procedures, and specifications needed by information systems to communicate.
- Semantic, which confirms that all exchanged data among different systems have the same meaning.

- Organizational, concerns about re-modeling of procedures and processes adopted by the government in order to provide services at the right time to stakeholders when needed.

2.7 Conceptual Framework

This research has a conceptual framework as illustrated in figure 16 below, which explains the methodology followed in this study whereas its terms are fully defined in the literature review. It has the proposed method for interoperability among PMoH electronic system.

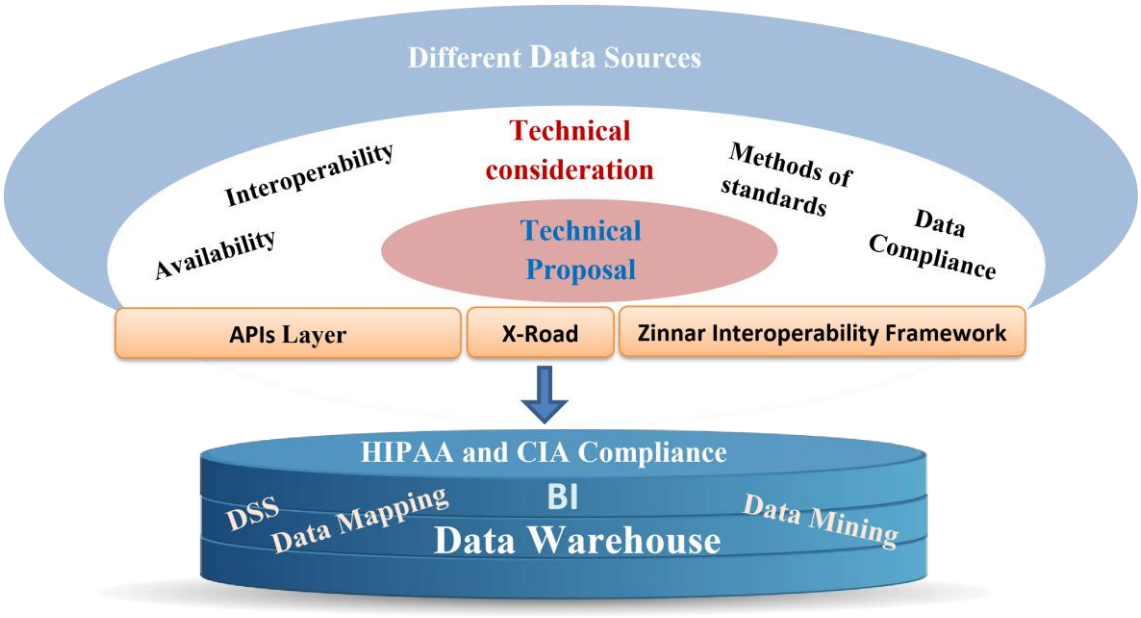

Figure 2.16: Conceptual Framework

The conceptual framework highlights the following concepts:

- Data sources:

The different electronic health applications such as digital registries and surveillance systems functioning in the ministry of health to support health by providing needed data and used in this research to extract data from to feed the proposed data warehouse.

- Technical proposal:

The proposed data warehouse model for solving interoperability among different electronic systems in PMoH taking in consideration the following terms that support the implementation of such model:

- Standards' methods in healthcare: different standardization approaches needed to ease the implementation of interoperability of healthcare electronic systems.
- Availability: focused on availability of accurate health data generated from different electronic systems that provides policy and decision makers with a powerful tool depend on evidence-based information to take the right action at the right time.
- Data compliance: the rules, regulations that health data must have in order to be shared, and exchanged among different stakeholders accurately and safely without breaching the privacy and confidentiality of patients.
- Interoperability: A term used to allow different electronic systems to share data and use it regardless of vendors or locations in an understandable format.

- APIs Layer:

Data elements related to each electronic application defined through the designated API to exchange and share data among them as needed.

- Zinnar Interoperability Framework:

This framework adopted by the Palestinian government to help in the implementation of interoperability and data exchange between different electronic applications and local ministries and organizations, and therefore allowing integration of data into the proposed data warehouse by handling the vocabulary, meaning, structure, codes, and business rules relating to the exchange of data.

- X-Road:

  A data exchange layer used by the Palestinian government with a technical and organizational environment. It allows exchange of data between different databases and information systems owned by various Palestinian organizations and ministries in a secure and independent platform using standardized SOAP protocol.

- HIPAA and CIA Compliance:

  HIPAA contains different rules and standards to safeguard patients' data such the Privacy Rule, Security Rule, and Breach Notification Rule. Whereas CIA model serves as a guiding principle for designing an infrastructure securely. It has three main components that the proposed healthcare warehouse must adopt:

  Confidentiality, integrity, and availability.

- Data Warehouse:

  A method proposed for solving interoperability among digital applications and systems in PMoH by collecting data from many sources and storing it in one place after cleaning and transforming into needed standards and format to prepare it for analysis, reporting and data mining in order to support decision-making process.

2.8 Summary

The literature reviewed for international, regional and local studies related to mapping electronic systems in term of interoperability and availability as well as different data warehouse models adopted as a solution of interoperability in healthcare settings. The following chapter explains the methodology adopted in this research.

Chapter Three

Methodology

3.1 Introduction

This chapter discusses the methodology adopted to conduct this study. It sheds light on the scope of this descriptive study about mapping electronic systems in PMoH in term of interoperability and availability.

3.2 Study Settings

This study conducted in Palestine/West Bank mapped different electronic applications running in PMoH, such as Avicenna electronic system that is the core system handling patients' data and operating in governmental hospitals and some primary healthcare directorates and clinics scattered all over West Bank (These include (Palestine Medical Complex, Jericho hospital in the middle, Rafedia, Alwatini, Salfit, Qalqilia, Tulkarem, Jenin, and Tobas hospitals in the north, Biet Jala, Hebron, Dora, and yatta hospitals in the south, in addition to Ramallah, Qalqilya, Nablus, and Hebron primary health directorates and their designated clinics). It has more than two million medical records for Palestinian patients living in West Bank according to (PMoH/General Administration of Information Technology, 2023).

Another important software examined was DHIS2 platform that accommodates different electronic applications such as MCH, mammography, and Covid-19 Surveillance System running in primary healthcare directorates and other related health clinics and centers. In addition to governmental health insurance application that collects data about insured people, their dependents, and their payments, as well as e-referral application that collects data about Palestinian patients referred to other hospitals outside the

governmental hospitals and treated based on their governmental insurance type that covers also their invoices, PACS system that manages all medical images such as CTs, MRIs, and normal X-rays for patients treated in different governmental facilities, in addition to other administrative applications used in different PMoH departments, such as drug management system, general store supplies including medical disposables management, and other applications deal with Covid-19 pandemic such as results.moh.ps and vaccine.moh.ps that provides people with their result tests online whereas vaccine registry deals with all data related to Covide-19 vaccination.

3.3 Study Design

To map the current electronic systems running in PMoH facilities and health centers in term of interoperability and availability by this descriptive study, finding the gaps, identifying the challenges and different factors affecting the availability of data and the implementation of such interoperable electronic systems and applications.

3.4 Study Population and Sample

The population of the main key persons managing electronic systems in PMoH is small so they all included in this study, The population of this study consists of the key persons in charge of running the different electronic systems in PMoH, the general director of general administration of information technology, the acting general director of the general administration of information technology, the IT person responsible of DHIS2 electronic system, and the three IT employees responsible of managing and supporting the PMoH data center (head of networks' division, head of networks

security division, and the systems engineer) that accommodates the different electronic systems.

3.5 Data Collection

The researcher followed the qualitative approach to conduct this study so personal interviews were used to complete the picture about the current status of electronic systems and their readiness in terms of data availability and interoperability since interview is a strong qualitative tool to examine the views of the targeted audience. The researcher followed the semi-structured interview approach with the key IT professionals responsible for managing and supporting the different electronic systems to figure out the status of data availability and interoperability.

The researcher prepared a list of questions to ask, specific and up to the point as shown in Appendix (2). The research questions and the literature guided the author to ask the intended questions. The interviews conducted in this study with key IT professionals responsible for giving support and managing the different electronic systems running in PMoH, all interviews were in person and arranged before and took from an hour to an hour and a half, some interviews were conducted by online calls, interviews were conducted in Arabic language and detailed notes were taken during the interviews.

3.6 Study Methods

The researcher got the approval of PMoH to conduct this study based on a signed letter of cooperation between PMoH and Arab American University – Jenin (see appendix (1)), and therefore managed to map and identify current electronic systems, registries and surveillance systems in PMoH based on the knowledge of the researcher and its experience as a general director of the general administration of information technology

at PMoH as well as the interviews conducted with different IT employees working in the general administration of information technology at the ministry of health whether computer engineers, programmers or administrative ones and classified such systems into four sections:

- Avicenna, which is the backbone system running in governmental hospitals, creates a unified electronic medical record for each patient visits governmental hospitals for treatment, and can be shared among hospitals through authorized permissions and credentials.
- DHIS2 is a primary platform running in the primary healthcare directorates and clinics and accommodates many applications such as MCH and family medicine. It deals with aggregated data and events like birth and death and is coordinated with PNIPH and managed by a country team formed from both PMoH and PNIPH.
- Applications that intersect with other ministries and institutions such as GHIMIS and RTA.
- Other applications that serves different facilities and departments inside PMoH such as e-referral and health insurance applications.

The researcher studied these mentioned electronic systems focused on their functions; and how they serve individuals, ministries, and other stakeholders in the country identifying existing gaps either technical, legal or cultural, it also identifies challenges, barriers, and factors of success mainly in the focus fields of this study, availability and interoperability leading to a clear picture about these electronic systems that contributes to solving the issue of interoperability among them.

The author worked in the IT field since 1996 and occupied many positions from giving technical support to different applications running in the ministry of health offices in

both Ramallah and Nablus as well as the person in charge of the early health insurance application and became the of IT department as one of the main departments of general administration of health insurance, the researcher then became the general director of general administration and information technology reporting directly to both minister and deputy minister of health, according to the organigram of the ministry for the last fifteen years.

These different positions provided the researcher with a clear image and a very good knowledge of the different electronic systems from purchasing to fully operating, plus the full support from her excellency the minister of health to the researches conducted by different employees in the field of information technology as shown by a formal letter to the president of the Arab American University/Palestine (see appendix (1)) to enhance the current status for the sake of improving health services presented to Palestinian people; this enables the researcher to access and study any needed application or electronic system to fully understand and identify the challenges of data availability and interoperability in particular inside PMoH and from outside mainly the status of information technology in the Palestinian government in general.

The researcher as a general director of information technology enabled him to be a member of many governmental committees related to the information technology representing

PMoH such as Zinnar interoperability frame work, X-Road, E-services and many others. The researcher headed the committee of the National E-Health Strategy (2022 – 2028) membered by WHO, PNIPH, UNRAWA, and the private sector, finalized its action plan to fully manage the different electronic systems related to health and their generated data not only in the ministry of health but at the national level with all

stakeholders whom their work intersects with PMoH and contributes to health of Palestinian people. The author used many terms in the online search for finding suitable articles covered subject of the study using different databases, web sites such as (world health organization, ministries of health, and public health institutions), and PubMed and google scholar search engines, and published in English language because of the availability for the last ten years, focused on suitable ones.

This study also reviewed many documents released by the Palestinian cabinet, PMoH, and MTIT to better understand the Palestinian context and environment pertaining the electronic systems shedding light on the regulations, rules, presidential decrees and decrees by law that govern the implementation of such systems to help making data available and ease the implementation of interoperability.

The documents reviewed were:

- The Information Security Policy document, which gives clear guidelines about the security of information systems implemented in the government and the rules that govern the exchange of information among governmental ministries and between government and other stakeholders (the researcher was one of the members who participated in getting this document ready).
- Tech and Management cluster published by the Palestinian government for the years 2021 – 2023, which analyzed the status of technology and general administration in Palestine that aims at the optimal usage of information technology towards the achievement of Palestinian digital economy, and having the following strategic goals that help in data availability and interoperability:
  - Strengthening the infrastructure of telecommunication and information technology.

- Raising the level of performance, efficiency, transparency, and justice through governance and digitizing governmental services.
- Strengthening international partnerships in the fields of technology and innovations.
- Capacity buildings in the fields of programming, technical sciences, data science and artificial intelligence.
- Fostering the legal environment needed for the functioning of technology sector and general administration.

- The sectorial strategy for telecommunication and information technology 20212023.
- Digital Transformation Policy for Palestine that finalized in 2019 by a technical support from Economic and Social Commission for Western Asia (ESCWA) represented by a local consultant and a national team of experts and specialists in digital technology formed from both governmental and private sectors. The policy sets guidelines for digital transformation in a safe way based on Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis for the status of information technology in Palestine identifying barriers, challenges, and factors of successful transformation, which contributes to achieving interoperability, and availability of reliable data.
- The sectorial strategy for health 2021 – 2023.
- The use of electronic governmental e-mail and the internet document.
- Many Decrees by law were reviewed, such as Electronic Crimes number 10 for the year 2018, the right to access information for the year 2018 and the electronic

transactions for the year 2013 to understand the legal situation regarding digital systems that fosters the implementation of interoperability and data availability.

To see the status of data exchange between PMoH and other governmental ministries or other stakeholders, the author interviewed the general director of Governmental Computer Center at MTIT to understand the current environment of the Palestinian information technology and the steps taken by the ministry to facilitate the availability the exchange of data between different ministries. The researcher also interviewed the general director of e-government at MTIT to have more details regarding X-Road, its goal, and its architecture as well as Zinnar interoperability framework, lead to the suggestion of the adoption of both the governmental X-Road and Zinnar by the proposed framework plan to exchange data securely and guarantee its integrity.

The researcher also searched the literature concentrated on the electronic and surveillance systems used in healthcare settings such as hospitals and public health organizations; the availability of data generated from them and the significant impact of interoperability among them in the health of patients and people, concentrated on three dimensions: availability of data, interoperability, and data compliance relating to electronic and surveillance systems in health domain and reviewed challenges, barriers and factors affected these three dimensions.

In addition to articles related to the adoption of information technology used in the battle against Covid-19 in the last years and the importance of available data generated used new technologies and its roles in controlling and reducing the spread of pandemics and new diseases providing new ways of treatments for better health outcomes and safer world.

Depending on reviewing the literature, studying the above-mentioned documents, the interviews conducted, and analyzing the mentioned electronic systems running in PMoH, the author proposed a national data warehouse framework plan to solve the issue of data availability and interoperability among various electronic systems in PMoH, the framework plan extracts data from different sources regardless its locations and functions to enable all stakeholders to benefit from such data in a seamless manner without affecting privacy, confidentiality, and security.

The national data warehouse framework plan has an APIs layer to solve the issue of interoperability among different electronic systems so as data elements for each application has to be defined clearly through the designated API and any two electronic systems should exchange data between them using their APIs, storing it in their databases and send it to the warehouse via the ETL layer that extracts, transform and load such data. Any data generated according to the proposed plan has to comply with Zinnar interoperability framework adopted by the government in order to confirm its quality, ease its exchange, and use among different ministries and other stakeholders from outside the government. It ensures data integrity and semantic interoperability.

Keywords such as interoperability, adoption, implementation of electronic or digital systems in healthcare, privacy, security, confidentiality, data integrity, data exchange, and data sharing were utilized in the search process.

3.7 Summary

In this study chapter, the researcher provided the study setting and the method followed through this research. The next chapter highlights the main outcome of the

study, which is the proposed framework plan for solving the interoperability among different electronic applications in PMOH (Palestinian eHealth Data Warehouse).

Chapter Four

Proposed Palestinian E-Health Data Warehouse

4.1 Introduction

In an era of increasing reliance on technology and data-driven decision-making, healthcare systems around the world are recognizing the need for efficient and centralized data management. Palestine is no exception. The establishment of a Palestinian National eHealth Data Warehouse holds immense potential for enhancing healthcare services, optimizing resource allocation, and improving overall health outcomes.

The idea of suggesting such solution for a national eHealth data warehouse in PMoH came from the need of exchanging data among different electronic systems and use it by policy makers to raise the quality of services presented to Palestinian people.

The researcher suggested implementing such a framework plan that composed of different layers as shown in figure 17 which are explained in details in the main components of the data warehouse section; based on the findings in the literature as well as the infrastructure and the available resources that PMoH as a governmental organization had. PMoH has many electronic systems. These electronic systems generate huge amount of data that can play a primary role for future planning in Palestinian healthcare management and services. The main data sources existed in PMoH and can provide a rich information to policy and decision makers are Avicenna, PACS, GHI-MIS, E-referral, DHIS2, and many more as explained before.

PMoH terminology and classifications such as ICDs as well as healthcare standards as

HL7 and DICOM are utilized in the existing electronic systems running in the ministry. Zinnar interoperability framework and X-road are adopted and provide both a solution for semantic interoperability and secure channel to exchange data.

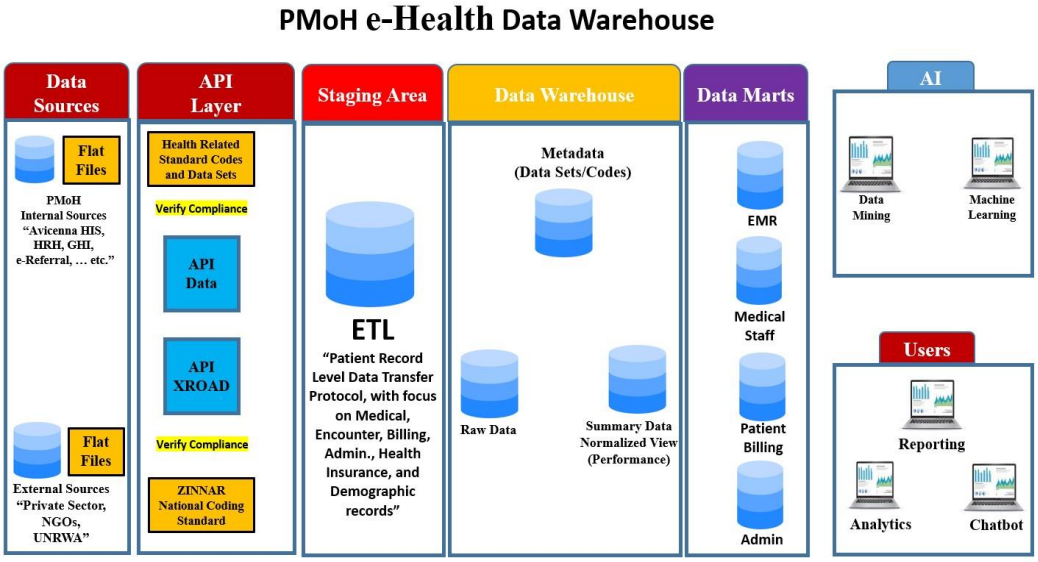

Figure 2.17: Proposed Data Warehouse

The researcher explored the other elements that are missing and not found in PMoH by searching the literature and took the advantage of many elements suggested in different methods and architectures adopted by different countries as a solution for healthcare interoperability. These elements include APIs, staging area, ETL tool, unified database or data warehouse, data marts, machine learning and data mining tools.

4.2 Strategic Goals of a National E-health Data Warehouse and Implications on Public Health Policies

A Palestinian National eHealth Data Warehouse can help achieve several strategic goals, benefiting both the government and the public. The primary objectives include:

- **Monitoring Healthcare Costs and Optimizing Services**

By observing trends in healthcare costs, decision-makers can identify areas that have the most significant impact on the government's budget. A national eHealth data warehouse can collect data from both public and private sources, allowing for a comprehensive view of healthcare expenditures. This information enables decisionmakers to devise strategies to contain costs, optimize services, and ensure financial sustainability.

- **Planning for Health Service Provisioning and Detecting Health Trends** the data warehouse can record health service utilization, providing valuable insights for planning and provisioning healthcare services. By analyzing patterns in healthcare utilization, decision-makers can identify areas with high demand and allocate resources accordingly. For example, if the data warehouse shows a significant rise in Diabetes Type II services utilization, decision-makers can focus on implementing educational programs in schools, promoting proper eating habits, exercise, and preventive measures.

- **Tracking Adherence to Medical Quality Guidelines**

The eHealth data warehouse facilitates the monitoring of adherence to medical quality guidelines. By integrating data from various sources, decision and policy-makers can assess the quality of care provided and identify areas for improvement. This information ensures that healthcare services meet established standards, leading to better patient outcomes.

- **Integration of Health Data for Better Budget Allocation and Long-Term Planning**

One of the key benefits of a national eHealth data warehouse is the integration of health data with social, economic, and financial information. By bringing together these diverse datasets, decision-makers can gain a holistic view of healthcare needs and allocate budgets more effectively. This integration enables long-term planning and the formulation of evidence-based policies that address the broader determinants of health.

"Health in All Policies (HiAP)" approach defined by WHO acknowledges that the health of population is mainly influenced by policies direct behaviors outside of the health sector rather than being just a by-product of health programs. Health and health inequality could possibly be impacted by policy in every area of government. Adopting a HiAP strategy tries to address policies that have an impact on issues like environment, agriculture, education and development of economy in order to make them supportive of overall health and health equity. This shows the importance of integration and data exchange among different organizations and institutions in both public and private sectors as well as Academia.

The proposed framework plan will collect data from different data sources in PMoH as described in the following sections to shed light on the main digital applications that provides a large amount of data.

4.3 The Need for a Palestinian National Data Warehouse

While these systems collect and manage data within their specific domains, there is a need to integrate and harmonize the data for comprehensive analysis and decisionmaking. A national eHealth data warehouse would serve as the central

repository for all healthcare-related data, bringing together information from the PMoH systems, private health institutions, research organizations, and other relevant sources.

The need for a national data warehouse arises from the following reasons:

- Data silos: Currently, healthcare data is stored in separate systems, leading to fragmented information and limited data sharing. A data warehouse would break down these silos and enable seamless data integration.
- Holistic view: A national data warehouse would provide decision-makers with a holistic view of the healthcare landscape, encompassing data from various sources. This comprehensive perspective is crucial for informed decision-making and effective resource allocation.
- Data analysis capabilities: By consolidating data in a single warehouse, advanced analytics and data mining techniques can extract valuable insights by identifying trends and patterns from available health data. These insights can support evidence-based policy formulation, healthcare planning, patients' outcomes and identifying patients at high risk, and quality improvement initiatives.

  Data mining has a positive influence on disease surveillance and outbreak possibilities. It can detect fraud related to insurance claims and play a crucial role in delivering personalized medicine and allowing treatment interventions to specific group of patients. It allows to identify improvement areas as well as to measure the effect of a medical intervention. It fosters researchers to support evidence-based medications.
- Data governance and standardization: A national data warehouse allows for the implementation of standardized data governance practices, ensuring data quality,

integrity, and security. It establishes common data definitions, formats, and protocols for data collection and sharing.

- Interoperability: The data warehouse can facilitate interoperability between different healthcare systems, enabling seamless data exchange and collaboration among stakeholders. Interoperability promotes efficient data utilization and eliminates data duplication.

4.4 Attributes of the Data Warehouse

A national eHealth data warehouse possesses several key attributes that make it an effective solution for healthcare data management:

• **Topic Focus**

The data warehouse designed specifically to focus on healthcare-related data, including clinical, administrative, financial, and population health information. It encompasses a wide range of data elements, such as patient demographics, medical history, diagnoses, treatments, healthcare utilization, and outcomes.

• **Time-Variant**

The records in the data warehouse provide information from an historical point of view and the record should contain an element of time, whether explicitly or implicitly (e.g., encoded in the primary key of the record).

• **Non-Volatile**

Simply put, once a data is inserted in the data warehouse it stays forever (i.e., it cannot be deleted once inserted). The only allowed operation will be loading data (after extraction and transformation) and querying it.

• **Homogenization of Data**

As shown in the above figure and the list of systems that PMoH uses, there will be a need during the design phase to establish of a standardized unit of measurement for all similar data regardless of the source of data. The linage of the data must be preserved, and a standard established for consistent naming conventions, format, and encoding of the data elements (i.e., data dictionary).

• **Data Integration**

The data warehouse integrates data from multiple electronic sources in PMoH including EHR, GHI-MIS, MCH, PACS and others. By aggregating data from diverse sources, decision-makers can gain a comprehensive and multi-dimensional view of the healthcare landscape.

- **Data Storage and Management**

The data warehouse employs robust data storage and management technologies, ensuring the secure storage and efficient retrieval of vast amounts of healthcare data. It utilizes techniques such as data partitioning, indexing, and compression to optimize data storage and retrieval performance.

- **Data Governance and Privacy**

The data warehouse incorporates data governance policies and privacy safeguards to protect the confidentiality, integrity, and availability of healthcare data. It adheres to relevant data protection regulations and implements appropriate access controls to ensure that only authorized individuals can access and use the data. It involves managing the lifecycle of the health data.

• **Data Analytics and Reporting**

The data warehouse provides advanced data analytics and reporting capabilities, enabling decision-makers to derive meaningful insights from the data. It enables automatic and schedule reports. It supports ad hoc queries, data visualization, trend analysis, monitoring key performance indicators, and predictive modeling, empowering and supporting them to make evidence-based decisions and to improve quality of care based on those data-driven analytics.

• **Chatbots**

A chatbot is a software built to imitate chat with people mainly through the internet. It utilizes Natural language Processing (NLP) to conduct conversation with human by understanding and responding to questions and queries.

Chatbot can supply users with information needed in certain situations to support them such as pandemics like Covid-19. In this proposal for healthcare data warehouse, Chatbot can help patients to schedule an appointment with their healthcare providers, which lowers waiting time by identifying patients whom need immediate interventions and whom can wait. It can also send them notifications about their medications.

 Interoperability and Data Exchange

Interoperability is a fundamental attribute of the data warehouse, facilitating seamless data exchange and interoperability between different healthcare systems and stakeholders. It enables health providers to have a comprehensive clear picture of patients' information. I t supports standard data formats, communication protocols, and interfaces to enable efficient data sharing, coordination, and collaboration. It supports research and management of public or population health. It enables patients to better access to their information.

4.5 The Main Components of the Data Warehouse

4.5.1 Data Sources

PMoH has the following main data sources as mentioned by General Directorate of Information and Technology at PMoH:

- **Avicenna**

PMoH has embarked since 2010 on a set of initiatives to implement the EMR throughout the governmental hospitals and some primary healthcare clinics. HIS, also known as Avicenna, is centralized database, client/server medical Enterprise Resource Planning (ERP) system deployed in governmental hospitals and some primary healthcare clinics and in some private hospitals as a primary source for the EMR.

This centralized system provides a uniform and standardized set of rules for all the data entered including ICD standard, unified services codes. It validates the patient's demographic data (name, ID, date of birth) through integration with other governmental databases (Ministry of Interior) and PMoH databases such as government insurance system and others. It is the core application in PMoH E-Systems and a significant tool needed by decision and policy-makers for better planning at three levels; central, district and national. The combination of these three levels promotes clinical and medical patient care activities in both hospitals and Primary Healthcare Clinics (PHCs). This includes reducing medical errors, reducing expenditures and enhancing consistency and quality of data.

Avicenna also helps Administrators to manage daily business and operations in both hospitals and PHCs such as human resources mainly the efficient use of these limited resources as well as the financial resources.

It also helps researchers and decision makers to get and analyze data regarding patients to enhance medical services internally across program areas and externally with PMoH partners.

Avicenna is an electronic record that covers many modules and functionalities such as inpatient and outpatient information, registration, appointment scheduling, radiology, laboratory results, blood bank information, maintenance, and drug management like prescription, ordering, and tracking.

The Avicenna health information system (HIS) is active in every facility where it is has been implemented. It is heavily depended on for basic management of patient in the different wards and for hospital top management decision-making. Facilities use

Avicenna for reporting of administrative nature and for inform resource allocation at the facility or hospital. It helps track patients from admission till discharge (Health Information System (His) Assessment Report, 2015).

The electronic application or system enables healthcare professionals to input, access, and follow up information of patients in an efficient way more than paper based system used before, leading to improve care quality for patients with greater accuracy, efficiency, and accountability for healthcare professionals or workers (Health et al., 2018).

The system lacks data quality related to different data elements such as diagnosis or procedures. This area must have revised and tracked in order to make sure that all data quality components are met. Data must be complete, accurate, and consistent in order to be valid and reliable.

The system is a proprietary commercial software, which means that PMoH does not own the source code and therefore it will not have the ability to customize it according

to needs such as connecting external devices without involving the Turkish developed company but it has an open source license to use it as needed in West Bank. Avicenna supports exchange of information and interoperability with others systems but it has to be done by the developed company; currently the system is linked to ereferral application, governmental health insurance electronic application, Road Traffic Accident application, and PACS system but needs fully integration with such systems running in the ministry of health. It also connected with Ministry of Interior (MOI) through an API.

The current version is a desktop version and the currently used infrastructure needs to be improved to handle the large volume of data and to comply with international standards in term of security, privacy, confidentiality, licensing, and high availability.

The system is backed up to a Disaster Recovery center located in Nablus. The site is a backup site for the main database in the data center in Palestine Medical Complex.

There is no cut over automatically to the disaster recovery center if the main Data Center is down. The DR will manually configure in order to operate when the main database is down in the data center and it takes minimum two hours to run.

PMoH has created the national e-health strategy with different stakeholders in the country in order to govern the different electronic systems and the digital transformation by adopting the various dimensions that involves policy, legal, and legislation guidelines as well as security, privacy, and confidentiality of health data.

- **Picture Archiving Communication System (PACS)**

An application that manages and archives medical images used by governmental hospitals in West Bank. PACS is a medical imaging technology used to securely store and digitally transmit electronic images and clinically relevant reports. The use of

PACS eliminates the need to manually file and store, retrieve and send sensitive information, films and reports.

These medical images include normal X-rays, Ultra sound, CT and MRI. The application is running in 12 governmental hospitals; Al Watani hospital in Nablus city, Hebron Hospital, Beit Jala hospital, Jenin hospital, Jericho hospital, Palestine Medical Complex in Ramallah city, Qalqilya hospital, Rafidia hospital in Nablus city, Salfeet hospital, Tubas hospital, Tulkarim hospital and Yatta hospital in Hebron area. PACS system is a web-based application that stores data locally in each hospital in a central database and in the cloud as well.

The radiologist in any governmental hospital with the right permission can access any image of the patient in any hospital; read it and write the needed report. The radiologist can follow up with his patients and can view their images from any part of the world by accessing their data that are stored in the cloud. The application solved the issue of lacking specialized radiologists in the governmental hospitals. The system needs to be extended to the rest of the governmental hospitals

The system is integrated with HIS running in the different hospitals so any physician can request his or her needed patient's medical images from the PACS system and write the necessary report on HIS.

- **Government Health Insurance Management Information System (GHI-MIS):**

A centralized system that tracks all insured persons on the government health insurance system. The main aim of the system is to manage the financial and eligibility criteria for insured persons and determines the benefits allowed for each insured person according to his or her insurance policy.

Governmental Health Insurance (GHI) is a social health insurance schema that provides healthcare coverage for the Palestinian people according to their economic capacity. Income earning Palestinians can enroll in the GHI through their employers or individually by paying a registration fee and a fixed or salary-deducted premium paid on periodic basis (monthly, quarterly or annually). Those Palestinians receiving social welfare support from Ministry of Social and Development (MOSD), the unemployed gets support from Ministry of Labour (MOL) and those in special categories or with special needs sponsored by government to receive governmental health services without the need to pay premiums or fees, (the Palestinian government pays their fees/premiums). GHI is compulsory by law for government employees and pensioners, and is effectively compulsory for Green Line workers, but is optional for all other social and economic groups in society.

The GHI-MIS aims to improve the efficiency of GHI business processes and extend the range and quality of services offered and data collected to/from General Directorate of Health Insurance (GDHI), PMoH, partner institutions and beneficiaries.

GHI-MIS is a centralized database application accessible through a web application architecture that has many functional interfaces: web portal interface to provide the internal GDHI and PMoH users (primary business users) with the needed support, web portal interface to support partners (institutions and organizations), web interface to give GHI beneficiaries and Palestinian individuals requested functions.

The system has provided access to the primary, secondary and tertiary levels of PMoH facilities to verify the insurance status of any person requesting services under an insurance coverage.

The application will have a mobile application interface in order to check the legibility of access by users of public health clinics and other ministry' departments connecting remotely. It integrates with Avicenna health information system and the electronic Referrals.

The system integrates other partners such as MOSD, MOL, MOI, Ministry of Finance (MOF), and Palestinian Pension Agency… etc. GHI-MIS system enables individuals and institutions to pay electronically through credit card, e-banking and direct bank deposit payments.

- **E-Referral System**

A centralized management system to process, monitor, and administer referrals of citizens to health facilities outside the network of the Ministry of Health. The application is connected with Avicenna since the process of referring patients starts at the governmental hospitals. Avicenna, electronic health insurance application, and ereferral systems must fully integrate with each other in order to complete the process of transferring patients in a digitized way.

The e-referral system standardizes the flow of patients' referrals, making sure all beneficiaries (e.g., the referring hospital, medical referral committees, the Service Purchase Unit, and financial and medical auditors) are able to approve or follow up the referral and its cost as needed, in addition to producing regular reports to help PMoH in evidence based decision-making (Achievements, 2016).

- **Road Traffic Accident (RTA)**

A registry that contains all road traffic accidents that require hospitalization and treated in a government Emergency Department (ED). The information pushed to the national police department and integrated with other sources (private hospitals).

- **Palestine Human Resources for Health Observatory (HRHO)**

The application has about 350 Indicators including sex distribution, age group distribution, health facilities, pre-service training, availability of Health Workforce in Vulnerable Areas, density, distribution based on geographical locations, and registered health workers. The application has 36,294 registered Health Workers distributed on 5326 Health Facilities. (Human Resources for Health Observatory, PNIPH, 2021)

A health information system collects data and produce reports on health professionals that address health workforce issues, identify challenges within the health sector, design strategies, allocate the workforce geographically, and develop informed policies.

- **PMoH Birth and Death Registry**

A centralized system tracks all births and deaths occurred in PMoH facilities or reported to them from other hospitals.

It exchanges information regarding births and deaths between both ministry of health and ministry of interior. It has a positive impact in both government and citizens because it saves time, efforts, and guarantees that the data exchanged is accurate and up-to-date.

- **Palestine Cancer Registry**

CanReg5 is an open source tool to input, store, test, and analyze data related to cancer patients. It has modules to do data entry, quality control, consistency checks and basic analysis of the data.

The Palestinian Ministry of Health established Cancer Registry that covers both Gaza and West Bank. The registry is population-based, which provides annual reports. The main goal of the registry is to define the volume of the cancer's burden in the country and identify trends of cancer's incidence and prevalence in addition to mortality.

- **Online Examination**

Palestine Medical Council (PMC) established in 1998 as an independent, financial, scientific and legal entity in order to raise the level of medical and healthcare in Palestine.

PMC gives comprehensive training modules for different medical specialties, sets up standards and specifications for the accreditation of hospitals and health centres qualified for giving the needed training of physicians in addition to the issuance of specialization certifications to physicians who meet the criteria and pass PMCs comprehensive exams.

PMC launched Palestine Medical Council E-Learning and Accreditation System (PMC-EAS) to achieve its goals of raising the level of medical healthcare using a fully automated system. It is a web-based application and every physician has the ability to register in PMC website (www.pmc.ps) and log in to the system from anywhere having internet services.

- **General Supply Management System**

A centralized information system that manages all medical disposable supplies and non-medical supplies and used by the government health facilities to renew their supplies by placing orders through the system.

It is an oracle application, started 1997 to manage material inventory in the warehouses of the PMoH and work to regulate and restrict the movements of materials in terms of input, output, borrowing and destruction so it tracks all transactions. It helps users to inquire about material balances, inventory and traceability, and regulates purchase bids, orders from suppliers, in addition to querying supplied materials, and the remaining quantities. It is used by different pharmacies in governmental hospitals and primary

healthcare directorates to manage the purchase process form different suppliers and to distribute drugs internally among PMoH related facilities.

Governmental hospitals and primary health directorates request the needed drugs from the drug store electronically then fully tracked by Avicenna. It is the same process for primary health directorates running Avicenna whereas other directorates manage the whole process by the drug store application itself.

The application operates in central drug store, central supply store, and disposables' store.

The system generates reports as needed to the top management in PMoH to plan for future purchase and locate the financial resources depending on the analysis of data generated from the system.

- **COVID-19 Vaccination Registry**

It is a portal to register people for Covid-19 vaccine, through which, PMoH followed a protocol with cooperation with WHO to determine the priorities of vaccination based on age and health status of the registered people. The system also provides people with vaccine certificate that contained Quick Response (QR) code in order to scan and read from those who concern especially for travel purposes

- **COVID-19 Results Registry**

A Centralized information system that manages the samples taken from potentially infected citizens, results of the tests and provides an API for both individuals and other PMoH and government agencies to check on the status of citizen using the person's identification number.

- **Continuous Professional Development (CPD) for Health Professionals Electronic system**

In order to deal with the complexity of health environment, healthcare professionals need to develop their learning at a deeper level. For these reasons, PMoH adopted a national electronic system for continuing professional development of healthcare workers and linked it to licensing and accreditation in cooperation of academic institutions, universities, and research centers to improve quality of health services provided by qualified health workers.

The electronic system tracks in-service training instances, identifies performance standards, manages tutors, coordinates training instances, manages training participants, tracks CPD credits, and generates reports for monitoring, planning, and identifying challenges and gaps.

- **Pharmacy.Moh.ps**

It is a portal used by different local companies to manage drug registration and prices, account credentials given to each user. It has many modules such as changing the price of registered drug, request pricing for imported drugs, as well as for the sake of exporting and registration of local drugs. The beneficiaries of such system are pharmaceuticals companies, drug stores and factories .

- **DHIS2 Applications**

A series of applications built on top of the open-source framework District Health Information software 2 and utilizing Postgres database. The applications mainly used in clinics of primary healthcare to track mother and child health, mammography, family practice, school health education, and dental services…etc.

- **Mother and Child Health E-Registry**

The MCH e-Registry is a case-based system that has dashboards, which ease feedback and monitoring process. It is an application that covers reproductive health gestational services from care of antenatal, postnatal to newborn.

The MCH e-Registry has Decision support system (automated and Interactive clinical national guideline), Performance of care providers on specific indicators related to quality, SMS messaging system which alerts women at risk or those who need special follow up and treatment care, and Real-time National Routine Statistics.

MCH supported by WHO. The system built as efforts of Palestinian ministry of health and PNIPH. It implemented in PHCs managed by the ministry of health.

All targeted clinics equipped with needed infrastructure and devices such as personal computers, servers, internet services and network connectivity. It has a structured data entry system contains electronic checklists, highlighting high-risk pregnancies, and supporting healthcare providers with needed clinical management.

MCH focuses on health issues concerning pregnant women until the day 42 after delivery and newborn until 28 day old, such as access to recommended prenatal and well-child care, infant and maternal mortality prevention and newborn screening.

It is a valuable tool for different stakeholders' care either providers, supervisors, policy makers, or interested researchers. The MCH e-Registry has built data continuity, which enables the healthcare system towards creating continuity of care.

COVID-19 Surveillance System: the system created as a quick response to the spread of COVID-19 virus in Palestine. PMoH, PNIPH and the DHIS2 country team (IT members from both sides) collaborated in joint efforts using their own capacity and built on DHIS2 platform in a customized way that fit in the context of Palestine. The system

reflects the case definition and reporting information of WHO such as sociodemographic, method and source of infection, exposure and travel in addition to laboratory test results as well as outcomes of health incorporated with case management criteria of PMoH. The surveillance system has the power of creating needed indicators for better tracking of Corona disease.

The core team built the system taking in consideration both requirements of PMoH and standards of WHO to track requested information nationally at the case level, and created needed dashboards with country-oriented indicators. The system characterize and classify Corona cases, either suspected or confirmed, as well as health status (recovered, stable, or infected). Interoperability of data guaranteed through PMoH official web site (site.moh.ps).

- **Mammography e-Registry**

According to PMoH cancer ranked as the second cause of death in which breast cancer comes first in women. Diagnostic mammograms are used to test for cancer of breast after symptoms appear whereas screening mammograms are used to test for the illness in women before symptoms or signs which leads to the deduction of the illness related morbidity and mortality.

Mammography e-registry is a web-based patient system that helps providers of care identifying the risk factors for registered women. It is built in order to track and followup information regarding woman-undergoing scanning; the file of a patient is then accurately stored in a centralized digital system.

The primary aim of Mammogram e-Registry is to enhance quality and completeness of data regarding every woman undergoing mammography scanning for the sake of better follow up and tracking. It also develops the performance of mammography program by

gathering and reporting information as well as using data at the levels of national services delivery in order to support decision and policy makers with evidence-based processed data.

The system creates hundreds of indicators at the national level in addition to routine statistics, shared with PMoH different technical departments. It improves healthcare providers' follow-up, ensuring continuity of care. It also helps policy and decision makers to manage breast cancer risk factors effectively and foster early detection and prevention.

- **Communicable Diseases Surveillance System**

It is a continuous process to gather, analyze and explain to better plan and assess the health programs to identify the needs and adopt the needed measures on time by decision and policy makers for monitoring and prevention in order to response quickly and take the right intervention.

The system tracks diseases, projects spread and monitors diseases for better control and actions. The core aims for case-based surveillance system: are monitoring the trends of the illness in order to act and treat at the right time, stop the spread of the disease, and identify the high-risk groups. It also explain the cause of illnesses or deaths for better prevention in the future and analyze the results of health programs to change plans related to the epidemiological status.

the case based surveillance covers many disease such as AIDS, Meningitis, Typhoid and paratyphoid fever, Tetanus, Brucellosis, Hepatitis, Leishmaniosis, Severe Acute Respiratory Infection Cases, suspected Measles and suspected Rubella, Acute Flaccid Paralysis, and Tuberculosis. The system has Performance and quality indicators in addition to Real-time National Routine Statistics.

- **Family Practice Electronic System**

It is a project coordinated between PMoH and PNIPH, which pave the way of achieving Universal Health Coverage (UHC) and create the family health file. The electronic health information system contains the child file, file of adult patients above 18 years old and the planning file of the family. The file of the family health will interoperable with None Communicable Disease (NCD) patient's file.

The family practice electronic system should cover clinics located in different governorates distributed all over Palestine. It follows members of family from birth to death.

These are the main applications running currently in the ministry of health that built upon DHIS2 platform. They are all have a crucial role in providing the necessary data with other electronic systems mentioned previously for better health management. This is where the importance of proposing the Palestinian National Data Warehouse that will provide a single version of truth for PMoH decision making and forecasting. It will contain historical and commutative data from multiple sources (see figure below) with primary focus on the medical encounters, demographic information, cost of services, and insurance.

4.5.2 APIs Layer

Depending on the ministry needs, all the various digital applications or data sources mentioned above as shown in figure 18 below have to create their own Application Programming Interfaces (APIs) to be part of the proposed solution for solving interoperability issue defining standardized data elements related to each application according to the format and standards requested by PMoH.

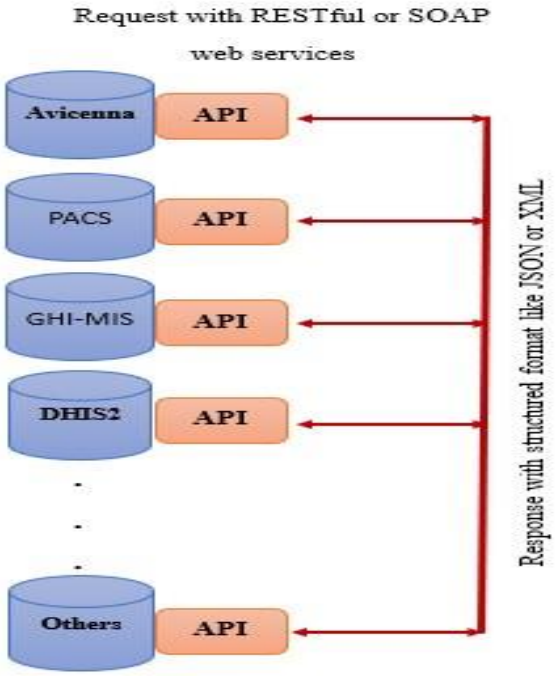

Figure 4.1: API Layer

Interoperability between two systems through APIs involves seamless exchange of data allowing electronic systems to work together regardless of differences in designated technologies. This interaction is defined by API endpoints that work as bridges between electronic systems. The APIs enable systems to send requests and receive responses in a structured format, typically utilizing protocols such as HTTP/HTTPS, and data formats like JSON or XML through RESTful or SOAP web services. The electronic systems communicate by invoking API methods, handling authentication and authorization ensuring data integrity and security during transmission. This allows different electronic systems to integrate their operations, share real time information and improve their capabilities without the need for direct access to each other's internal databases.

Interoperability between Avicenna and E-referral systems for example can be facilitated through their proposed designated APIs, when a patient needs an operation or any other medical treatment outside PMoH; the two systems exchange vital information via

secure API calls. Avicenna initiates the process by sending patient data and the specific medical requirements to E-referral through predefined API endpoints. The E-referral then processes the received information, checking eligibility, authorization, and logistic details for external medical services. This data exchange occurs in a structured format like JSON or XML ensuring compatibility between the two systems. The E-referral system may also communicate back to Avicenna confirming approval, sharing updates on the referral process or requesting additional information. The integration ensures smooth, coordinated process for patient referrals, leveraging authentication, authorization, and secure data transmission protocols to maintain the integrity and confidentiality of patient information. This API - driven interoperability streamlines operations, reduces manual interventions, and enhances the efficiency of healthcare service delivery.

4.5.3 Extraction, Transformation, and Loading Tool (ETL)

Reasons behind adopting ETL job for the proposed data warehouse based on the following facts:

- The sources of data in the PMoH utilize are diverge. They include relational databases using Microsoft SQL Server, Oracle RDBMS, MySQL and Postgres to name a few engines. In addition, some information is stored in structured files such as Comma Separated Values (CSV), XML, and Excel.
- To add complexity to the data scene, different systems use different data standards (for example, Ministry of Interior for governorates vs the Palestinian Central Bureau of Statistics).

Therefore, there is a layer to perform data in-sourcing, transformation, and specialized tools for performing the needed conversions and the changes needed to transform data into a unified/standardized format in the Data warehouse. This layer will contain ETL Tool as shown in figure 19 below.

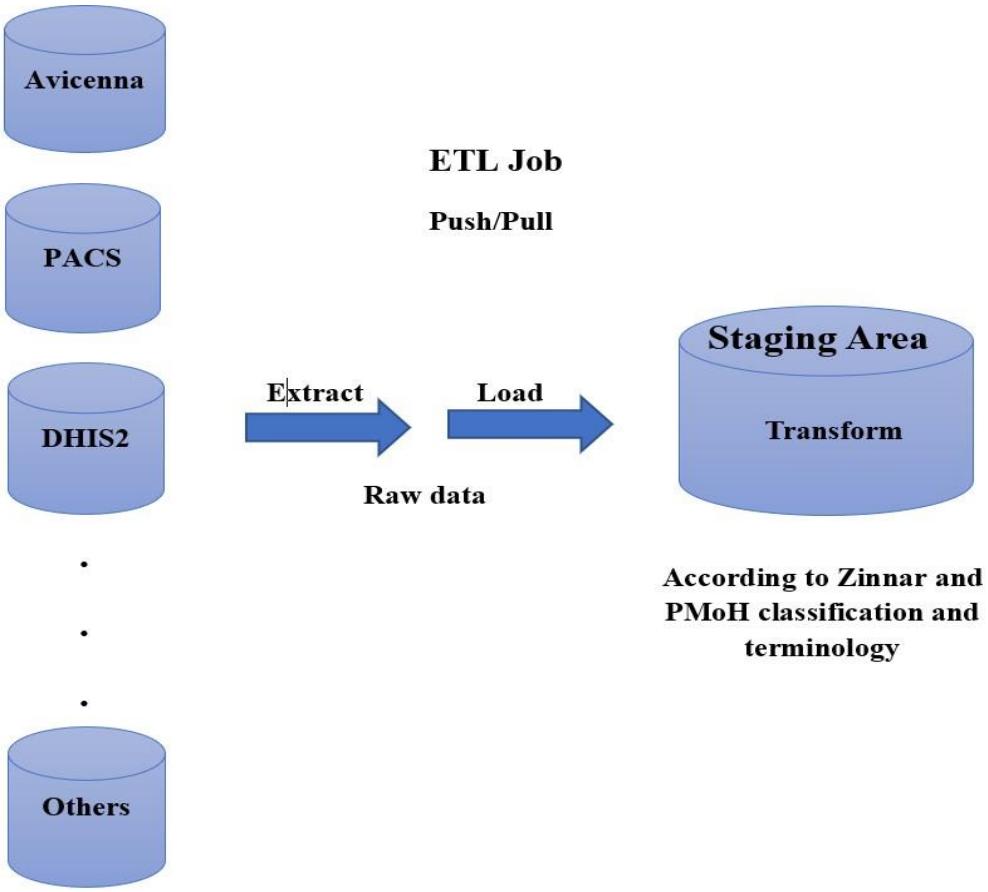

Figure 4.2: ETL Layer

The ETL layer will perform the following tasks where necessary:

- Anonymize data to maintain patients' privacy.
- Remove unwanted data before loading into Data warehouse.
- Harmonize the data types and names for same data elements for data arriving from different sources.
- Populate missing data with defaults per the business logic rules.
- De-duplicate data arriving from multiple data sources.

The ETL operates to retrieve or pull the needed data by connecting to the source databases directly to get it on schedule. the source system can also push the information from its databases to the staging area.

There is a need to do full extraction the first utilization of the ETL tool from the various data sources in order to ensure that all needed data is captured and entered in the data warehouse. For minimizing the effect of such extraction on the performance of the targeted sources of data, it is recommended to arrange the full extraction to run during off-peak hours.

This will eliminate the impact off the full extraction process on different data sources usage during regular work. On the other hand, an incremental extraction should schedule to extract the data that subject to change or update only from the targeted applications or sources which lowers the time to complete the process and reduces the influence on the data sources as well as the data warehouse itself.

In order to conduct the incremental process, there should be a way to follow any updates or changes that happen in the data provided from the data sources by utilizing different approaches such as Change Data Capture (CDC) and timestamps.

Incremental process needs to be arranged according to the scale of data changes and the requested requirements of the data warehouse based on chosen period or interval (per hour or per day). In order to guarantee data integrity during the process of extraction there is a need to test the validity and quality of data to make sure that the extracted data is according to the needed standards and requirements.

Once the extraction process completes, the transformation job starts to transform the extracted data to the format needed according to the rules of Zinnar framework that guarantees the structure and format of data is compliance with the specific rules built by the framework. In addition to that, it should be validated against the international classifications of diseases standards used by PMoH especially the diagnoses of patients as well as HL7 and DICOM to confirm that integrity of the transformed data for the sake of effective analysis. The transformation should be designed in a way that ensures the performance of the whole process, avoids consuming time, and guarantees better usage of the available resources.

Transformation based on record batches by adopting the available framework, APIs, the functions supported by the database management system, the computing resources, and the capabilities offered by the ETL tool as well as parallel processing that divided data into different partitions. These two approaches can operate complex transformation and big data in the healthcare data warehouse and lower the time of processing.

The extracted and transformed data stored in the staging area temporarily for further validation as needed before loading it into the warehouse. The load process then loads the whole data when initially used for the first time (full load), after that an incremental load implemented to load only data records subject to change which can applied using timestamps or CDC. The ETL job can further transform the formatted loaded data into

the data warehouse to subsets known as data marts to facilitate quick access and efficient utilization of data according to user needs as shown in figure 20 below:

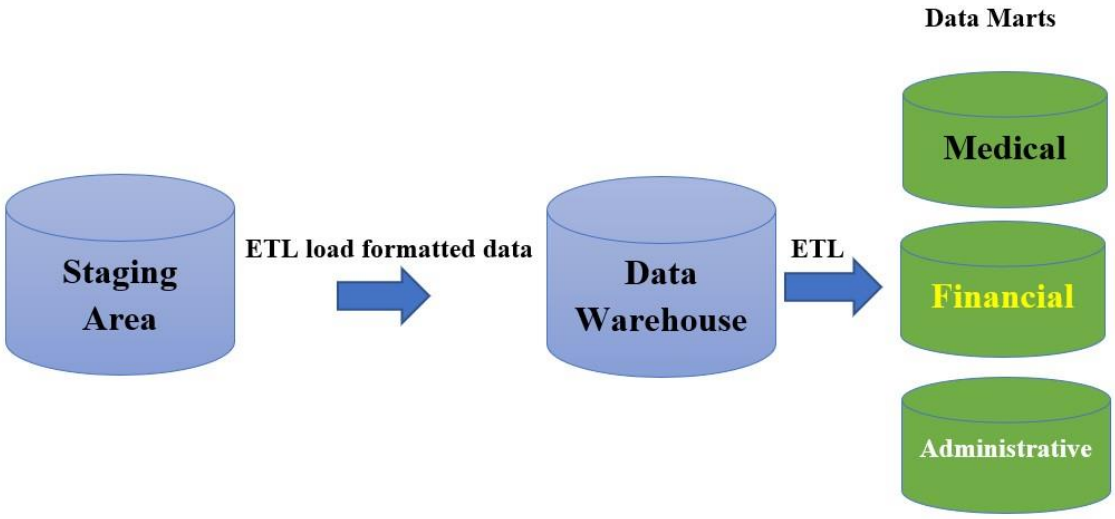

Figure 4.3: Loading Data from A Staging Area into Data Warehouse and Creating Data Marts

It is advisable to run performance tuning and error handling mechanisms in addition to indexes and defined partitions to enhance the query process and troubleshooting.

4.5.4 Palestinian Interoperability Framework "Zinnar" and X-ROAD

The Palestinian government through a committee formed from different ministries under the supervision of ministry of telecommunication and information technology, created an interoperability framework, called Zinnar as shown in figure 21. It allows and guides data exchange and paves the way for e-government services at three levels Government to Government, Government to Citizen, and Government to Business.

As stated by the general director of e-government at MTIT, the main aim of Zinnar is to facilitate exchange of data among the state's institutions.

The framework work consists of five items:

Government Ontology: this component ensures clear, accurate common understanding of the different concepts used in the various ministries that represents the Palestinian government. It concerns about both government data meaning as a static concept and meaning of government processed and services as dynamic concept.

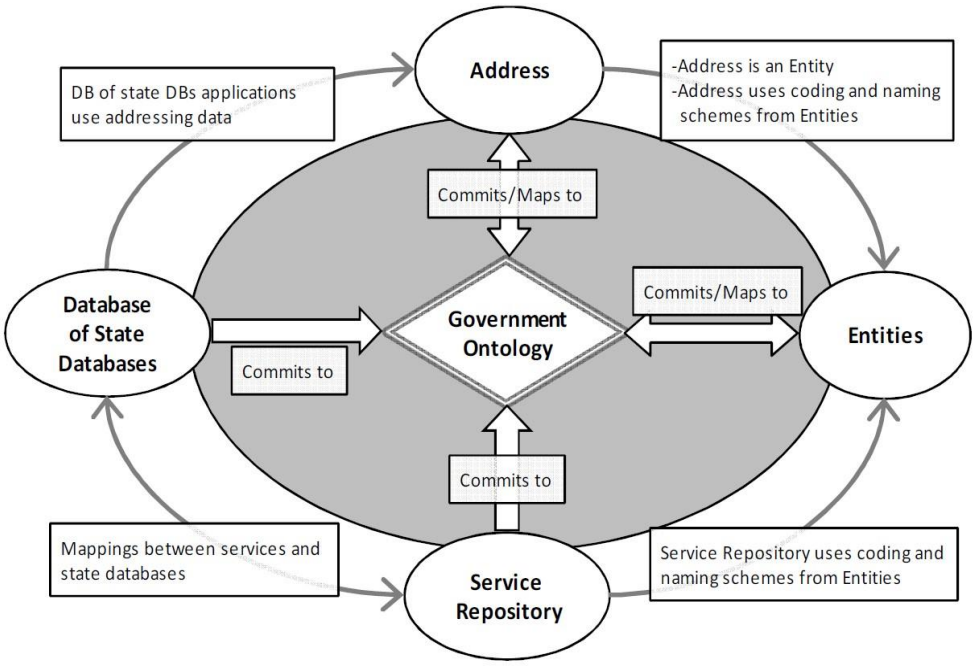

Figure 4.4: Zinnar Interoperability Framework, (M Jarrar et al., 2011).

Entities: this item accommodates all codes, classifications, and naming schemas as defined by the government at the national level such as cities, marital status, religion …etc. (M Jarrar et al., 2011).

Addresses: is where database of addresses saved including postcodes presented by Geographical Information System (GIS) web application.

Service Repository: it contains metadata about electronic services provided by the government as web services clearly defined. It has services for citizens, business, and government.

Database of databases: it has all metadata about electronic services provided by the government such as database name, data types, time of creation, registered records number, and owner of the database and so on (M Jarrar et al., 2011).

The Palestinian interoperability framework facilitates semantic interoperability and data exchange between different systems and organizations, enabling seamless integration of data into the data warehouse.

Zinnar handles the vocabulary, meaning, structure, codes, and business rules pertaining to the exchanged data.

Whereas X-Road as clarified by the general director of e-government at MTIT aims to exchange data securely among different state's institutions utilizing central security servers and security certificates servers.

The data exchange layer X-Road is a technical and organizational environment that enables secure and platform independent data exchange between the state's databases and information systems. Platform independence is achieved by using standardized SOAP protocol.

The different Palestinian ministries communicate with each other and exchange information services using the governmental network X-road launched 2015 with the cooperation of the Estonian government, which is a digital interoperability centralized system with a powerful infrastructure owned and managed by the government. All digital services must follow Zinnar interoperability framework rules and formats. X-road is a technical platform that assures the security of transmitted data by encrypting it according to the international standards using public key encryption. The Palestinian government has built a governmental portal called Houkomty through which each

individual can have an account with only single sign on that enables him or her to access all the digital services presented by the government.

The portal allows individual to pay electronically for the services they receive such as renewing the driving license or paying for the health insurance.

Figure 22 illustrates the X-Road architecture for presenting government services:

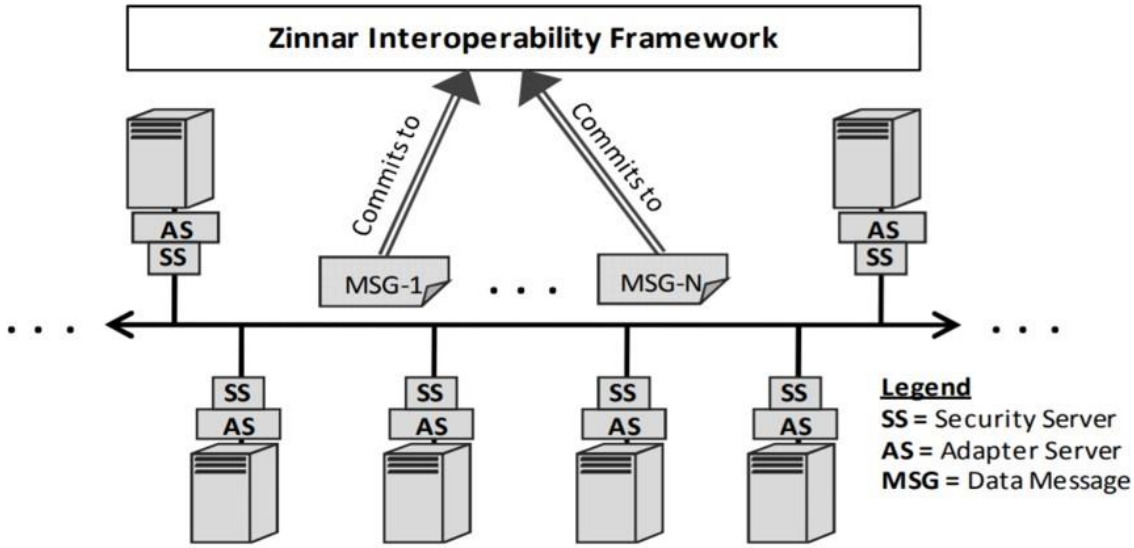

Figure 4.5: The E-Government Architecture, Source: (Jarrar et al., 2011)

Each ministry has two servers, adapter and security, the security server is a dedicated data exchange server between consumers and service providers that encrypts and decrypts the messages of the data received, sent and manages the permissions of the calling institution or organization. The adapter server is a web server that manages the X-Road requests from the different users; it adapts the requests to the unified format (M Jarrar et al., 2011).

The Government Computer Center in the Ministry of Telecommunication and Information Technology (MTIT) hosts and operates the system.

The goal of this platform is to provide a core infrastructure that allows interoperability between state registries without compromising the security of the data and with capability of organic integration with existing systems.

Public sector institutions can connect their information systems with the X-Road and start exchanging data between each other using SOAP e-Services. This approach enables institutions to save resources, since the data exchange layer already exists.

The X-Road platform is open, secure and simple. Information systems based on different platforms can successfully communicate with each other simultaneously and their individual characteristics do not hinder this. The platform gives service providers and data-owners free hands to design and implement new e-Services while relying on the existing secure infrastructure. As illustrated in figure 23 below, each institution or ministry can connect to another one using predefined web services provided by X-

Road infrastructure through its designated API.

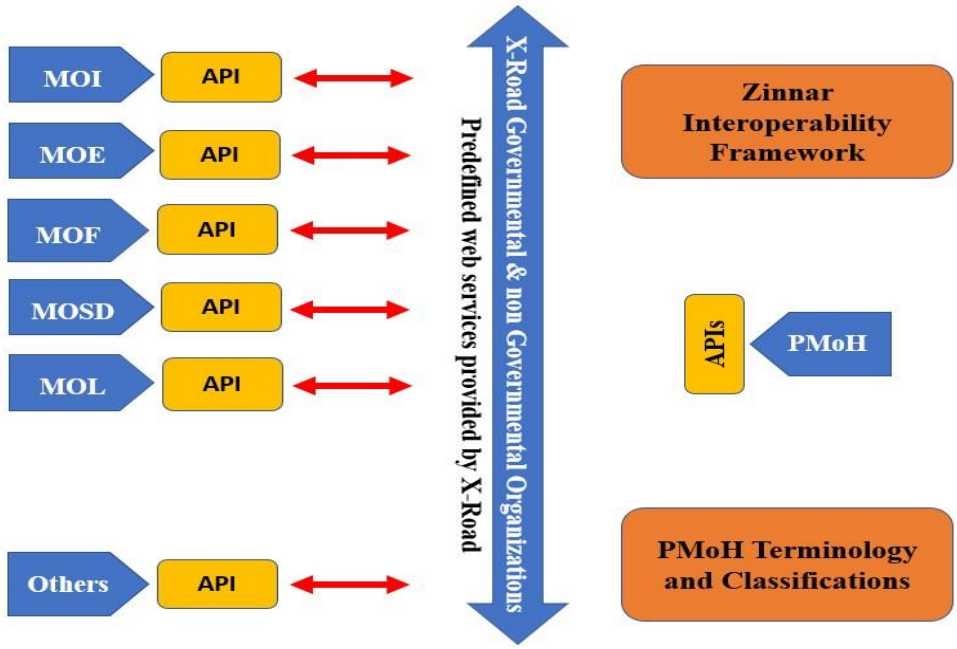

Figure 4.6: Connecting Different Ministries with PMoH Through X-Road

In X-Road, the service provider is a database that is providing predefined web services through X-Road infrastructure. The service consumer is an institution or organization that uses services provided by service providers.

4.5.5 Data Dictionary and Data Elements

- ❖ Data dictionary: A data dictionary is a central repository that contains metadata about the data elements in the data warehouse. It provides information on data structure, semantics, relationships, and attributes.
- ❖ Data elements definition: Data elements are the individual data components stored in the data warehouse. Each data element defined and described in terms of its meaning, format, and usage.

The following Meta information must maintain in order to maintain the Data Warehouse:

- ✓ What tables, attributes, and keys does the Data Warehouse contain?
- ✓ Where did the data come from, i.e., data lineage?
- ✓ What are the data refresh rates per data source?
- ✓ What are the business transformations that applied during the ETL stage?

The data dictionary and Data Element information (i.e., meta data on the warehouse) can be grouped into following classes:

- ➢ Technical data: Meta-information about the data warehouse's technical aspects, such as data sources, data transformations, and data quality measures, is crucial for understanding the data's reliability and validity.
- ➢ Business data: Meta-information about the business context, including data definitions, business rules, and data ownership, helps stakeholders interpret and use

the data effectively. It ensures that the data aligns with the organization's goals and objectives.

4.5.6 Data marts for Efficient Data Access and Analysis

Data marts are subsets of the data warehouse that focus on specific business areas or user groups. They designed to provide fast and efficient access to relevant data for specific analytical purposes, improving query performance and simplifying data analysis tasks.

The process of extraction and transformation builds those suitable data from the data warehouse and after that loaded into distinct databases with its own structure created for specific departments or user groups' purposes. Those data marts connected to the main database in the warehouse and developed on regular bases to maintain data integrity.

Users can access and examine information related to their particular area of concern using data marts such as finance, clinical, or quality assurance, which offer a more specialized and focused view of the targeted data.

They provide different stakeholders in PMoH easy access to their area of responsibility, which improves data usage and performance and therefore better analysis.

4.5.7 Data Mining and ML Tools

Machine learning and data mining tools are very important data warehouse components to enhance the capabilities of data warehousing applications in the healthcare sector, the integration of machine learning and data mining tools have gained considerable attention. Machine learning and data mining tools offer the potential to extract

meaningful insight data, improve decision-making processes, and enhance patient care. The integration of machine learning and data mining tools in data warehousing applications brings several advantages. Machine learning excels in recognizing complex patterns, detecting anomalies, and predicting future trends based on historical collected data. By leveraging these capabilities, healthcare professionals can gain deeper insights into patient health, identify potential risks, improve reporting skills and develop personalized treatment plans. Chatbot allows patients and other citizens to interact actively according to their needed data.

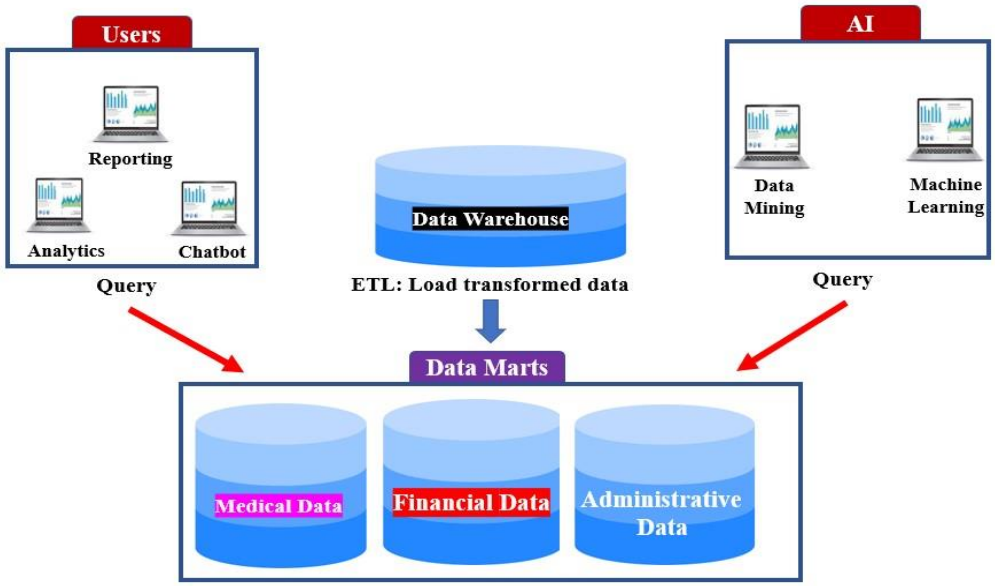

Figure 4.7: Data Analysis, Reporting, and Users' Queries

4.5.7.1 Machine Learning Platforms

Following are several available machine learning platforms:

- **TensorFlow**

TensorFlow is an open-source library developed by Google. It provides a comprehensive ecosystem for building and deploying machine learning. With its

flexible architecture and extensive documentation, TensorFlow is widely used in both research and production environments.

- **PyTorch Software**

PyTorch is another popular open-source deep learning framework. Known for its dynamic computational graph, PyTorch offers a user-friendly interface and excellent support for GPU acceleration. It is widely adopted by researchers and practitioners for its ease of use and flexibility.

- **Keras Software**

Keras is a high-level API written in Python. It provides a simplified interface to apply machine learning applications efficiently. Keras is built on top of TensorFlow and is known for its user-friendly design and fast prototyping capabilities.

- **Theano Software Tools**

Theano is a Python library that allows efficient mathematical computations. Although it is not actively maintained anymore, Theano remains a popular choice due to its speed and flexibility.

- **Caffe Software**

Caffe is a deep learning framework developed for speed and modularity. It is widely used for image classification and other computer vision tasks. With its easy-to-use interface and pre-trained models, Caffe is a popular choice in the research community.

4.5.7.2 Implementing an Integrated Chatbot with Machine Learning and Data Mining Tools for Warehouse Data Retrieval

the researcher recommends creating an integrated Chatbot with machine learning and data mining tools for efficient data retrieval from the proposed data warehouse. The

Chatbot offers users seamless access to relevant data and insights. For such implementation, PMoH should apply the following steps:

Step 1: Define Objectives and Requirements

Objective Definition: Clearly define tasks and goals of the Chatbot, specifying the type of information it should retrieve from the data warehouse.

Requirements Analysis: Identify needed data from the data warehouse, considering user queries, historical interactions, and contextual information.

Step 2: Data Collection and Preprocessing

Data Gathering: Extract relevant data from the data warehouse, ensuring comprehensive coverage of potential user queries.

Data Cleaning and Preprocessing: Clean and preprocess data to handle missing values, remove noise, and format it appropriately.

Step 3: Integration with Data Warehouse

Connectivity Setup: Establish a robust connection between the machine learning model, data mining tools and the data warehouse, utilizing APIs or database connectors.

Query Processing: Develop mechanisms for processing user queries and translating them into efficient queries for the data warehouse, ensuring compatibility with its query language.

Step 4: Chatbot Integration

Chatbot Framework Selection: Choose a suitable Chatbot framework (e.g., Rasa, Dialog flow) for building the user interface and managing user interactions.

API Integration: Connect the Chatbot framework with the machine learning model and data mining tools through designated APIs.

User Interface Development: Design and implement an intuitive user interface for the

Chatbot, providing a positive user experience.

Step 5: Quality Assurance and Deployment

Testing: Conduct thorough testing of the integrated system, including various user scenarios, edge cases, and data retrieval functionalities.

Optimization: Optimize the machine learning model, data mining tools, and Chatbot based on testing results, fine-tuning parameters for optimal performance.

Deployment: Deploy the integrated system in a controlled environment, monitoring for any deployment issues and implementing a rollback plan if necessary.

Monitoring and Maintenance: Set up monitoring systems to track the performance of the Chatbot, machine learning, and data mining tools in real-time. Regularly maintain and update the system to address evolving user needs and data changes.

Step 6: User Feedback and Iteration

Feedback Loop Implementation: Establish a feedback loop with end-users to gather insights for continuous improvement.

Iterative Development: Iterate on the machine learning model, data mining tools, and Chatbot features based on user feedback, ensuring the system evolves to meet user expectations.

The researcher also recommends forming a team to achieve this component of the proposed framework plan, clearly define the roles needed for implementing this intended component. The team should have data scientists, machine learning engineers, software developers, UI/UX designers, and a health domain expert.

- **Data Scientists and ML Engineers**

Hire persons who have a background in natural language processing (NLP), machine learning with proficiency in Python and good experience in frameworks like TensorFlow or PyTorch.

- **Software Developers**

The proposed team should include developers who have the needed experience to integrate the Chabot with the data warehouse to develop the needed APIs. In addition to full-stack developers with expertise in both backend and frontend.

- **UI/UX Designers**

Employ designers who have the expertise on how users interact with catboats and can create a friendly user interface.

- **Domain Expertise**

Having a health domain expert can provide valuable insights into specific health terminology, user needs, and contextual understanding for such Chabot.

- **Project Manager**

Nominate a project manager to oversee the entire process in order to align team goals, ensure effective communication, and keep the life cycle of such project on track.

- **Collaborative Tools**

Utilize collaboration tools such as Jira, Trello, or Asana to streamline tasks, monitor progress, and facilitate team communication.

- **Communication Channels**

Establish regular communication channels, including team meetings to foster clear and efficient communication within the formed team.

- **Training and Skill Development**

PMoH should provide opportunities for ongoing skill development and training as needed. Agile Development is a good approach to enable iterative development, continuous feedback, and adaptability to changes throughout the implementation. Quality Assurance is needed to test the performance of such Chabot, handle of edge cases, and deliver of accurate responses.

- **Feedback Loop**

Establish a feedback loop with end-users for continuous improvement. User feedback is invaluable for identifying areas of enhancement and refining the Chatbot model over time.

To find a team for building such Chatbot, PMoH can explore various avenues since the country lacks suck kind of expertise:

- **Online Platforms**

Websites like LinkedIn and Freelancer allow you to search for and connect with professionals in this regard.

- **Professional Networks**

Attend industry conferences, meetups, or join online forums related to artificial intelligence, machine learning, or Chatbot development. Networking with professionals in these spaces can help you find potential team members.

- **Collaborative Platforms**

Platforms like GitHub and GitLab are great for finding developers and data scientists who actively contribute to such project.

- **Tech Communities**

Engage with tech communities on platforms like Stack Overflow or specialized forums. You can find skilled individuals discussing and sharing their expertise.

- **Recruitment Agencies**

Consider reaching out recruitment agencies specializing in tech and AI. They can help finding suitable candidates based on specific requirements.

- **University Programs**

Collaborate with universities or research institutions. Often, students or researchers may be interested in working on such practical project.

- **Social Media**

Leverage different social media platforms to connect with professionals in the field. There are often dedicated channels or hashtags for such kind of collaboration.

Designing the security Infrastructure and Data privacy regulations

In the digital age, the protection of sensitive information is of paramount importance, especially when it comes to medical and patient data. Ensuring the design of the proposed healthcare warehouse covers the fundamental principles of the CIA model: confidentiality, integrity, and availability

Understanding the CIA Model

The CIA model serves as a guiding principle for designing a secure infrastructure. It encompasses three core components that the proposed healthcare warehouse must take in consideration:

1. Confidentiality

Confidentiality focuses on restricting access to sensitive information only to authorized individuals. In the context of medical and patients' data, it is crucial to protect records and ensure that they remain confidential.

2. Integrity

Integrity ensures that data remains accurate, complete, and unaltered throughout its lifecycle. Maintaining data integrity is vital to prevent unauthorized modifications or tampering, therefore safeguarding the trustworthiness of medical and patient records.

3. Availability

Availability ensures that the data and application are accessible to authorized users when needed. In a medical context, uninterrupted access to patient records is critical for healthcare professionals to provide timely and accurate care.

Securing Data Confidentiality

To achieve data confidentiality, several measures should be implemented:

- **Role-Based Access Controls**

Implement robust role-based access controls (RBAC) to ensure that only authorized personnel can access specific data. Assign roles and permissions based on job functions and responsibilities.

- **Encryption of Data at Rest and in Transit**

Encrypt data both at rest and during transmission. Utilize strong encryption algorithms to protect sensitive information, such as patient records, passwords, and personal identification data

- **Secure Authentication Mechanisms**

Implement multi-factor authentication (MFA) to strengthen the authentication process. This adds an extra layer of security by requiring users to provide multiple pieces of evidence to prove their identity.

Ensuring Data Integrity

To maintain data integrity, consider the following measures:

- **Data Validation and Sanitization**

Implement stringent data validation and sanitization techniques to prevent input of malicious or erroneous data. Use input validation mechanisms to verify the authenticity and integrity of the data being processed.

- **Regular Backup and Recovery**

Perform regular backups of the data warehouse application to ensure that data can be restored in the event of accidental deletion, system failures, or security breaches.

Regularly test the backup and recovery processes to verify their effectiveness.

- **Change Management and Version Control**

Establish a robust change management process to track and control modifications to the application and data warehouse. Utilize version control systems to manage software updates and ensure data integrity during the development and deployment phases.

Enabling High Availability

To achieve high availability, consider implementing the following strategies:

- **Load Balancing**

Implement load-balancing techniques to distribute the application's workload across multiple servers. This ensures that resources are utilized efficiently and provides redundancy in case of server failures.

- **Redundant Infrastructure**

Set up redundant hardware and network infrastructure to minimize single points of failure. Redundancy can include backup power supplies, network connections, and failover systems.

- **Disaster Recovery Planning**

Develop a comprehensive disaster recovery plan that outlines the steps to be taken in the event of system failure, natural disasters, or other emergencies. Regularly test and update the plan to ensure its effectiveness.

Data Privacy Protection for a HIPAA Compliant Healthcare Data Warehouse

In today's digital age, data privacy has become a critical concern, especially in the healthcare sector where the sensitive information of patients is stored and processed. Ensuring data privacy for the healthcare data warehouse must take in consideration through all phases of the design process whenever is applicable.

The healthcare industry, bound by stringent regulations, including HIPAA that sets standards for the protection of sensitive patient information, ensuring the confidentiality, integrity, and availability of electronic PHI. Designing a data privacy framework to protect the healthcare data warehouse requires a comprehensive understanding of HIPAA regulations and the implementation of appropriate security measures.

Understanding HIPAA Regulations

HIPAA encompasses various rules and standards to safeguard patient data. These include the Privacy Rule, Security Rule, and Breach Notification Rule. The Privacy Rule establishes guidelines for the use and disclosure of electronic PHI, while the Security Rule defines the security controls to protect electronic PHI. The Breach

Notification Rule mandates the reporting of any security breaches involving electronic PHI. It is crucial to adhere to these regulations when designing the data privacy framework.

Data Privacy Protection Requirements

To ensure compliance with HIPAA, the data privacy framework for the healthcare data warehouse should address the following requirements:

1. **Data Classification:** Classify data based on sensitivity levels to determine appropriate protection measures.
2. **Encryption:** Implement strong encryption algorithms to protect data at rest and in transit.
3. **Access Controls:** Establish access controls to limit data access based on user' roles and responsibilities.
4. **User Authentication:** Implement robust authentication mechanisms, such as twofactor authentication, to ensure authorized access to the needed data.
5. **Auditing and Monitoring:** Enable comprehensive auditing and real-time monitoring to detect and respond to unauthorized access attempts or suspicious activities.
6. **Incident Response and Breach Notification:** Develop an incident response plan to handle security incidents promptly and efficiently. Establish procedures for breach notification as required by HIPAA.
7. **Regular Security Assessments and Penetration Testing:** Conduct periodic security assessments and penetration testing to identify vulnerabilities and address them proactively.
8. **Employee Training and Awareness Programs:** Educate employees about data privacy, security best practices, and their roles in safeguarding patient information.

9. **Third-Party Risk Management:** Evaluate the security practices of third-party vendors and business associates and establish strong contractual agreements to ensure the protection of patient data.
10. **Data Backup and Disaster Recovery:** Implement regular data backups and robust disaster recovery mechanisms to ensure business continuity in case of data loss or system failure.
11. **Secure Development Lifecycle:** Integrate security into the different phases development lifecycle by following secure coding practices and conducting security reviews at each stage or phase.

4.6 Summary

In this chapter, we explained in details the proposed eHealth data warehouse as a solution for data availability and interoperability among electronic health systems running in PMoH, reasons for choosing such solution, main data sources, attributes and components of eHealth data warehouse are all discussed clearly. The next chapter includes the discussion part of the main findings as well as the study's recommendations.

Chapter Five

Discussion and Conclusion

5.1 Introduction

In order to achieve the objectives of this study and answer its research questions, the researcher conducted many interviews with key IT persons from both PMoH and MTIT. Depending on these interviews results and the expertise of the researcher, this study managed to identify the main data sources, their functions, their data elements, standards they have, and factors that influence the availability of data and the interoperability of electronic systems like security, privacy, confidentiality, data quality, and standards. It provided a framework plan to overcome these challenges and solve the issue of interoperability between different electronic systems, It also gets benefit of Zinnar Interoperability framework to solve semantic interoperability between PMoH and other ministries that intersect in its work with it, such as ministries of labour, development and social affairs, interior, and finance, in addition to the adoption of X-Road for exchanging information securely.

In this chapter other models of data warehouse proposed in the literature are explained and summarised and compared to the proposed solution.

5.2 Thesis Contribution

PMoH has implemented many electronic systems since its establishment regardless of the lack of financial resources since it believes in the primary role of such systems in presenting good quality of services to the Palestinian people. The challenges of making data available to stakeholders when needed as well as the issue of interoperability

especially in the Palestinian healthcare domain with various systems that have different format, standards, and technology.

Accessing such sensitive data without breaching security and privacy is a big concern.

This study aimed at finding the most applicable solution to solve the issue of interoperability in the Palestinian complex healthcare settings. For this reason, based on the available elements that PMoH has, the different approaches and models found in the literature for solving such problem, and the interviews conducted, the researcher suggested a framework plan to apply a healthcare data warehouse to solve the issue of interoperability by the APIs component, and to deal with the availability of data by adopting the ETL tool.

These models and approaches highlighted the importance of international standards, terminology, and classifications in health such as HL7, LOINC, DICOM, and different ICDs versions, in addition to using web services and APIs that help and contribute to solving the issue of interoperability.

The proposed framework plan to solve interoperability among various electronic systems in PMoH has many layers. The first layer manages the available data sources by building different APIs to create the needed data format and standards. The other layers take advantages of the available infrastructure in the Palestinian government, mainly Zinnar interoperability framework as a solution for semantic interoperability and X-Road as away to guarantee secure connection for exchanging data either internally or externally.

ETL layer extracts, transforms, and load the data to the warehouse after preparing it in the staging area according to the data marts and analyse such data to find trends and

insights by using machine learning and data mining tools as analysis layer and present the processed data to policy makers to better plan for the future.

5.3 Discussion Overview

To the knowledge of the researcher, this study is the first that conducted in Palestine to map the different electronic systems in PMoH in terms of availability and interoperability.

This study identified electronic and surveillance systems running in PMoH, as well as applications that exchanged data among them, and the methods adopted to facilitate the process of information sharing.

There are different types of interventions linked to electronic or digital health such as EHRs, mobile applications, tele-health, and web-based applications that contribute to population or public health (Benny et al., 2021).

Adoption of digital health for the sake of gathering needed information for action and quick response is different among developing and developed countries due to factors such as cost and expertise. Developed countries like United States and EU have implemented digital health in their health settings and domains. Applications of emerging technology such as AI are mostly utilized and developed in countries with high income whereas adoption of such technology still weak in countries with low income because of the lack of data quality and weak infrastructure (Alami et al., 2020).

Emerging technologies such as Internet of Medical Things (IoMT), Blockchain, Big data, Cloud Computing, Telehealth, 3D printing, Machine Learning (ML), and Natural Language Processing are high-tech applications widely use in rich countries but its usage in poor countries is recent. The need to utilize such technologies rise strongly the last years in order to collect data, process and analyse it on real time and make it

available to policy and decision makers in health and other sectors to better manage healthcare such as fight and control diseases and stop the spread of them. Countries all over the world used generated data from such new technologies to reduce the economic burden imposed by the viruses and to increase the safety of the world population.

All these technologies can play crucial role in availability and interoperability of healthcare data. By adopting Blockchain, enhancement of security related to health data can increase which allows only authorized users to access and manage it. IoMT and AI applications give providers of healthcare the opportunity to collect, and manage data in order to stop the spread of diseases and plan future treatment based on real and timely data that help in accurate diagnosis.

Cloud computing enables various stakeholders to share health data in an effective and secure way by allowing the coordination of healthcare services for the sake of the population health.

The spread of Covid-19 put tremendous pressure on the government and public health institutions to adopt new technology to follow, monitor, and detect infected cases as well as speeding up the process of testing (Li et al., 2021).

The researcher found no initiatives conducted in PMoH for the adoption of such new technologies due to the absence of expertise, regulations to govern the usage of them in the Palestinian health domain, the high cost of implementing them, the lack of needed infrastructure, implications of the Israeli occupation (the Palestinian government is struggling to get 4G internet services because of such implications), and concerns related to the privacy and security of healthcare information.

This study found no mobile applications used in PMoH to speed up the process of health data collection and make information available for decision making even in the

fight against pandemic of Covid 19 whereas such application widely utilized in healthcare settings worldwide.

The researcher believes that PMoH as a governmental organization controls and oversees the health sector in Palestine should focus on investing in new technologies since it is a good source to make health data available and ease the process of interoperability. It should strengthen the relation with private sector either directly with information technology companies or with other private investors facilitating the adoption of such technologies.

The partnership between public and private sector will facilitate the availability and interoperability of healthcare data by overcome the obstacles of implementation modern technologies which will benefit all parties especially patients.

The government will provide all necessary regulations, policies, and procedures whereas the private sector will supply the needed expertise and the financial resources; such relationship plays a primary role in sustaining business, keeping it functions, and serving patients with high quality care based on the availability and interoperability of up-to-date health data.

The government with the cooperation of academia should directs Palestinian students to scientific research related to data science and data analysis to advocate the local expertise and overcome the challenges and gaps in the Palestinian health context. The government needs to have public campaigns awareness to eliminate culture and resistant to change challenges in order to pave the road to successfully implement digital health to provide those in charge of health in Palestine with accurate, complete and clean data at any time as needed.

The researcher found that interoperability among various electronic systems in PMoH shared the same challenges and corresponded to previous studied in the literature in most of the time.

As appeared from the interviews conducted with the IT key persons in PMoH and their answers to the different questions (see appendix (2)) and the knowledge and expertise of the researcher as a top management person of the information and technology general administration in PMoH; the main factors affecting a successful implementation of interoperability can be summarized as:

- The high cost of achieving interoperability due to lack of financial resources (most of the projects regarding development of digital health depend on donors whom link the approval of such projects with the political situation and their own agendas).
- Culture is another important factor that affects the implementation of interoperability; yet lots of work need to be done to overcome this problem mainly resistance to change. This complies of what reported that Arab world has to overcome cultural challenges to use health information technology in a proper way (ALSADAN et al., 2015), so it is the responsibility of government with the cooperation of non-governmental institutions to advocate for the importance of interoperability to ensure exchanging of health information and using it to provide quality of services to the Palestinian people.
- Security, legal environment, and absence of regulating policies are also among factors that concern the issue of interoperability in PMoH that correspond to most of previous studies in this regard. The ministry should implement the Information Security Policy Document developed by the government to overcome these challenges. These issues highlighted by (Gavrilov et al., 2020) regarding the

challenges of interoperability in EU countries and also stated by (Muinga et al., 2020) about lack of policies that govern the information exchange process.

- Another field of interest concerning interoperability is standards that play a significant role for successful adoption of interoperability. Zinnar framework can play a primary role, so electronic systems in PMoH should comply with its format as well as other standards, terminology, and classifications implemented by PMoH for accurate and reliable data exchange with other ministries and institutions.
- Lack of financial and human resources affect sustainability of the overall electronic systems running in PMoH, without the integration of efforts between all the sectors that intersect in their work with health; sustainability remains a big issue.

The author encourages PMoH and other stakeholders mentioned in the national ehealth strategy to focus on the eight years action plan to govern and guide a good and safe digital transformation not only at the ministry level but also at the national level and therefore guarantee availability of data and interoperability among different electronic systems.

The concept of data warehousing proposed by the researcher is used worldwide by different countries either at the national level or at the organization level; the concept composed the main components of data warehousing with different approaches, standards and techniques such as HL7, APIs, and web services to achieve healthcare interoperability.

All models have data sources, some kind of middleware solution and a clean, processed, analysed, and then utilized database by different end users and stakeholders using different standards and protocols to allow for information exchange in a secure channel.

(Ronoh et al., 2018) framework for solving interoperability corresponds to our proposed approach in a manner suggested how to overcome factors such as data formats, lack of standards, fragmented systems, infrastructure and the lack of data governance. All these factors affecting the adoption of interoperability among various electronic governmental information applications in order to provide services to people in an efficient and effective way. Both approaches address technical and semantic interoperability as well as security.

The proposal of data warehouse in this study is different in its architecture from what had been proposed by (Georgi et al., 2018) to solve interoperability in healthcare settings. The model suggests a software library to connect a group of sensors using both proprietary (specific to a particular vendor) and standards (widely adopted by industry) protocols with the goal to reach any data by providing seamless links between these sensors. A software library is a collection of pre-written functions and codes used by developers to build or create systems or applications. As approach to solve interoperability, it can supply a set of tools, interfaces and protocols to ease communication and facilitate information exchange among different electronic systems. This model will operate by a third party of developers, providers and applications of health services in order to capture patients' data whereas our approach uses APIs and available standards.

(S. Jabbar et al., 2017) described a model that deals with prescribed medications for treatment of human diseased utilizing a new technology based on internet of medical things and cloud services and focused on semantic interoperability. While our proposed framework plan deals with all kind of healthcare data so it is more general and based on

the available infrastructure and standards whereas their model utilized hi-Tec technology.

(Gazzarata et al., 2015) and Amin et al., 2020 models based on SOA which means that every application or data source has services such as common vocabularies or computing processes that can be utilized to have access and enable exchange data with other applications or data sources, besides Gazzarata et al. built their model using a public cloud mainly to access the electronic health record resides there. These models' architectures differ from the researcher proposed framework plan architecture but it corresponds to Amin et al. in the way that uses web services provided by APIs layer to access and share the data, but differs from Gazzarata et al. since the data warehouse resides on premises (on the data center of PMoH).

Adel et al. focused on solving the semantic interoperability in electronic health records based on fuzzy ontology whereas our solution is a comprehensive one to solve interoperability in general, based on Zinnar framework for solving semantic interoperability.

(Bae et al., 2021) suggested a platform that enables patients to control their health data through approach known as MyHealthData to manage their personal health record ,which is differ from the researcher proposal. It utilizes mobile application by users to request medical information stored in hospitals and a relay server connected to the Blockchain technology by third party to guarantee integrity and security.

(Pai et al., 2021) approach that based on Electronic Health System to link all the users of HIS in India into one centralized place depending on a worldwide cloud database that allows all health providers to access the data on the EHR system and utilizes the resources of the cloud at the different levels of healthcare provided by the country.

This approach differs from our proposed framework plan since it allows access to data collected and stored in a unified electronic health record system using cloud technology while ours allows access to all health data collected from different electronic systems and stored in a warehouse; not only EHR.

(R. Jabbar et al., 2020) framework differs from ours since it based on Blockchain technology for ensuring data integrity when exchanging electronic health records mainly controlled by an "Access Management System"; Access Management System is a framework of processes, policies and technologies in order to control and manage the access to different resources for the sharing of electronic health records among various healthcare providers to protect data, maintain privacy and stop unauthorized access.

(Crichton et al., 2013) model uses Enterprise Service Bus that supplies a centralized bus to manage all links between different components; It is more expensive than API layer approach because of its advanced capabilities and its scalability. It is like the XRoad that utilized as the main bus for connecting different ministries and organizations in Palestine to share different services in a secure channel as described in the researcher proposed framework plan.

Crichton approach utilized a loose coupling concept that designs the system so as it allows components or services to function in an independent way, which means if one component or service fails, it will not affect the other, different concept architecture from PMoH proposed framework plan.

(Ayeni et al., 2018) framework has a different approach from ours since it allows patients directly to consult a licensed doctor regardless of their places via a web tool linked to a centralized server located in an associated cloud. Ayeni's approach focused

mainly in solving socialized healthcare interoperability that allows the direct contact between a patient and a chosen physician.

Rinty et al. approach based on loose coupling technology that enables organizations and providers to build their improvement without disturbing their current systems, distributed electronic health record to distribute the workload and HL7 standard as a solution to interoperability in developing countries. This approach differs in its architecture from PMoH approach although both approaches utilized HL7 for standardization.

The proposed warehouse model presented by this research to solve the interoperability issue in PMoH differs in its scope from the proposed technique by (AlZghoul et al., 2016) although APIs layer and ETL tool serve as a middleware layer. AlZghoul adopt an architecture of middleware software to allow different healthcare providers and patients to access health information effectively and efficiently as a solution to solve the inaccessibility of electronic health records in Jordan. This proposal is a comprehensive solution that covers digital systems in PMoH; electronic health record is one of them.

Jaleel et al. proposed a solution differs in its architecture form the researcher one in the way that based on IoMT devices cloud to allow different devices to upload and download data and share it among each other's.

Azarm proposal is simple; it consists of myPHR web site, APIs layer, and a cloud storage. The proposal focusses on a minimum data set for patients, which enables both patients and healthcare providers to access and update data stored in myPHR (personal health record) so Azarm et al has a different scope from the one proposed for PMoH that has a broader scope in addition to a premises storage or database.

The model proposed by Khan and Hoque is similar to the proposed data warehouse by the researcher in the way it utilizes ETL job and an interim area for storing transformed data (staging area) then loaded into a national health data warehouse. They utilize OLAP for online analysis and ad hoc reporting which can be achieved by machine learning and data mining tools.

Gavrilov et al. proposal is a wider concept from the proposed framework plan by the researcher since it highlights the issue of interoperability across-different countries adopting security measures according to General Data Protection Rule (GDPR) applied in the European Union countries. It also uses XML schema as a standard for exchanging data by utilizing a web service whereas PMoH model uses Zinnar and health standards such as HL7 and ICD.

PMoH IT team can build the APIs part in the proposed warehouse model for different applications to solve interoperability among them, but there is a need to invest in the infrastructure (software, hardware, networks) that is weak and old as well as investing in capacity building of the current IT staff, so a comprehensive training programs to improve the expertise of the personnel responsible of managing and maintaining different electronic systems is needed to ensure sustainability of such a warehouse. The comprehensive training program should cover but not limited to interoperability standards, data governance, system integration, data science, and cybersecurity for proper data management that enable all the stakeholders to plan well for better future health outcomes.

Managing health data in PMoH needs to be institutionalize and govern in a way that guarantees its accuracy and usage without affecting the security and privacy of patients.

The available health data still not fully used for decision making and not disseminated to those who need it and yet not analysed in a scientific manner as explained by those key IT persons whom interviewed by the researcher as well as the knowledge of the researcher in this regard. The researcher encourages PMoH have data management policies, mechanisms for data quality assurance, and data sharing agreements to ensure integrity and security of health information among different systems.

Based on the interview with the general director of computer center at MTIT, PMoH should make use of their infrastructure such as having a DR site to further ensure data availability and guarantee the continuity of different systems to function without any interruption.

PMoH can also use the governmental cloud located in MTIT to backup up its public health data and guarantee the proper use of such data without affecting the security and privacy or misuse of such data from any outsiders.

Self-financial support is necessary to provide the money needed for the development of both systems and human resources to guarantee the continuity of these systems and not to depend on donors only.

Reviewing the process of purchasing software applications and ICT hardware in the government is highly needed, it should focus on quality rather than cost. The government should plan this process well to ensure sustainability and continuity of services. The government should have the rules, regulations, and policies to lead the process of digital transformation in Palestine safely in order to guarantee all the needed components for interoperability and data sharing that comply with the Palestinian law.

5.4 Recommendations

- Develop the current infrastructure and invest in human resources responsible for supporting the different electronic systems by providing them with the necessary capacity building.
- Invest more in security measures, data quality, and data science.
- Create a specialized committee or group for data management and governance.
- Establish a framework for continuous monitoring and evaluation in order to assess the effectiveness of the implemented interoperability and availability measures.

Continuous audits, performance reviews as well as users' feedback in order to identify gaps and new challenges for further improvement and long-term sustainability.

- Build a unique health electronic record at the national level to solve the issue of data availability. This approach can capture health data from different data sources and update it whenever needed.
- Build a unified database for different electronic applications in the future, this will facilitate data sharing.
- Create an active - active DR site to guarantee functions and continuity of electronic applications so as work will not disrupt if any emergency thing happens for any reason.
- Advocate for health data sharing and exchange of information by having necessary campaigns awareness for both end users and top management.
- Increase the cooperation between PMoH and academia as well as the private sector to foster scientific researches in the field of data management and to get the needed expertise.

- Implement the eight years plan of the national e-health strategy.

5.5 Study Strengths

- It is the first study that identify the most important electronic health systems in PMoH highlighting the importance of interoperable systems and the availability of data in health domain.
- The proposed solution is the most applicable one and can lead to a successful implementation of interoperable electronic health systems and making data available.
- It fosters data driven decision-making for better health.

5.6 Study Limitations

- The study took place in West Bank only and did not take any electronic health systems running in Gaza strip due to political and geographical constrains.
- The study provides recommendations, design for an eHealth data warehouse, and has no chance to implement or test it due to time and cost concerns.

5.7 Conclusion

Based on the knowledge of the researcher as a general director of information technology at PMoH and the interviews conducted, the main electronic systems that serve Palestinian people have been identified and explored in details, these available electronic systems generate tremendous amount of health data and can provide many reports, dashboards, and health indicators that can support decision and policy makers to take the right action at the right time and plan for high quality healthcare services.

Unfortunately, these electronic systems are fragmented and need to be interoperable to ensure better performance and outcomes. The data collected from the current different electronic systems lack quality, data integrity is weak due to poor data management and absence of data governance body, in addition to the absence of political commitment. The infrastructure that serves the various electronic system needs to be developed to secure data and facilitate data availability and

interoperability.

Lack of money and lack of specialized IT personnel is the main challenge for having interoperable electronic systems and making data available, in fact it affects solving all other challenges such as infrastructure, security, and capacity building. Although some international standards are there, PMoH should have the necessary international standards when plan for acquisition of any future systems.

The proposed solution if implemented will have a great value and a positive impact on the health services provided to Palestinian people by ensuring interoperability making data available on time for evidence-based decision and policymaking for the sake of better treatment and healthy life.

5.8 Future Study

There is a need for future study in this regards that should focus on mapping electronic health systems among different healthcare providers in Palestine and test their readiness for interoperability as well as availability of such data on time. These studies should pave the way for having one electronic health record in Palestine (one patient one record).

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Appendices

Appendix (1): Letter of Study Approval

23 Jun 2019 11:45 HP Fax page 1

State of Palestine
Ministry of Health
Minister's Office

دولـــة فـلسـطين
وزارة الصحة
مكتب الوزير

al Quds

19/6/2019 16 23

الاستاذ الدكتور علي زيدان ابو زهري حفظه الله
رئيس الجامعة العربية الامريكية

تحية طيبة وبعد،،

الموضوع : التعاون بين الجامعة العربية الامريكية وقسم المعلومات الصحية في وزارة الصحة الفلسطينية لاجراء دراسات في مجال المعلوماتية الصحية والخدمات الصحية المقدمة للمواطن

تهديكم وزارة الصحة أطيب التحيات ، وبالاشارة الى كتابكم بخصوص الموضوع المذكور اعلاه ، يرجى العلم انه لامانع لدينا من الحصول على المعلومات الصحية اللازمة من طرفنا لاجراء الدراسات الصحية، على ان تزودونا بنتائج هذه الدراسات .

وتفضلوا بقبول فائق الاحترام والتقدير ،،،

وزير الصحة
د. مي الكيلة

الاخ ا.د. وليد ذيب المدهم
للاطلاع واجراءاتكم
19/6/2019

نسخة : معزوفة ابوكيل الساعد المحترم

Ministry of Health - Nablus- Tel.: 09/2384771/6 - Fax : 09/2384777
Ministry of Health -Ramallah- Behind Palestine Medical Complex
Tel.: 02/2964183 - Fax : 02-2964182
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وزارة الصحة - نابلس - تلفون : 09/2384771/6- فاكس : 09/2384777
وزارة الصحة - رام الله - خلف مجمع فلسطين الطبي
تلفون : 02/2964183 فاكس : 02/2964182
وزارة الصحة - غزة - تلفون : 08/2846949 فاكس 08/2826295

Appendix (2): Interview Questions

- What are the main electronic systems in PMoH?
- What applications built on DHIS2 platform?
- What are the types of data collected?
- Are these electronic systems exchange data among them?
- What are the challenges of data availability and interoperability?
- Do the electronic systems follow any international standards such as HL7, ICD, DICOM?
- Is the quality of collected data good enough?
- Are there any data analysis tools?
- Do policy and decision makers use the analyzed data for decision making?
- Is there any need for advance data analysis such as data mining and AI?
- Is there any connection between PMoH and other ministries?
- What is the technology used to establish the connection?
- Is there any disaster recovery site for the different electronic systems?
- What are the main challenges that the Palestinian government faces for sharing data?
- Does MTIT take any procedures t overcome such challenges?
- Can the different ministries utilize the infrastructure of MTIT?
- What is the vision of MTIT to facilitate data sharing?
- What is the main goal of Zinnar?
- What is X-Road used for, describe its architecture?
- Are there any information published ate the formal site of MTIT regarding Zinnar and X-Road?

- What steps does MTIT take to build Disaster Recovery Site for the government?
- Are there any backup lines available through the governmental network?
- Do you want to add anything else before we finish our meeting?

الملخص

موضوع الدراسة: مسح واقع السجلات والمراصد الصحية الإلكترونية في وزارة الصحة الفلسطينية ومدى إنسجامها مع التوجهات الإستراتيجية الوطنية للصحة الإلكترونية من حيث التوافقية والوفرة.

أنشأت وزارة الصحة الفلسطينية وطورت العديد من الأنظمة والتطبيقات الإكترونية منذ نشأتها عام 1994 من أجل جمع البيانات الإدارية والمالية والصحية لغايات تحسين خدمات الرعاية الصحية المقدمة للشعب الفلسطيني.

وفرة الأنظمة الإلكترونية وتوافقها له دور نوعي ومركزي في تزويد خدمات الرعاية الصحية وبالتالي تحقيق نتائج صحية جيدة. تبادل البيانات بين هذه الأنظمة والسجلات الإلكترونية ضعيف ولذلك فإن البيانات المطلوبة من قبل أخصائيي الرعاية الصحية وأصحاب المصالح الأخرين غير مكتملة وغير متوفرة في الوقت المناسب ولا يمكن الإعتماد عليها في إتخاذ القرارات بسبب النقص في التوافقية بين هذه الأنظمة الإلكترونية لأن صيغ بياناتها مختلفة بالإضافة إلى تحديات الخصوصية والأمن. قامت هذه الدراسة الوصفية بمسح السجلات وأنظمة الرصد الإلكترونية المتوفرة حاليا في وزارة الصحة الفلسطينية من أجل تحقيق الإستراتيجية الوطنية للصحة الإلكترونية والتي تهدف لحوكمة هذه الأنظمة الصحية الإلكترونية وإعطاء الدعم اللازم لجميع المؤسسات الحكومية والغير حكومية التي تتقاطع في عملها مع النظام الصحي على المستوى الوطني.

قام الباحث بالبحث في محركات البحث المختلفة والمواقع الالكترونية المتوفرة على الشبكة العنكبوتية مثل PubMed , Google Scholar لاغناء البحث وتحقيق أهدافه.

اقترح هذا البحث نموذج Warehouse يحتوي على عدة طبقات لجعل البيانات متوفرة حين طلبها من خلال جلبها من التطبيقات المختلفة العاملة في الوزارة باستخدام إطار التوافقية زنار)إطار عمل الإنطولوجيا(الذي تم تطويره من قبل الحكومة الفلسطينية لتأكيد تكامل البيانات، إستخدام الشبكة الحكومية الفلسطينية)X-Road(من أجل تبادل آمن للبيانات بالإضافة إلى إقتراح إستخدام طبقة خاصة بواجهات برمجة التطبيقات) APIs(المختلفة التي ترسل وتستقبل البيانات من خلال الأنظمة الإلكترونية المختلفة المستخدمة في الوزارة لتسهيل التوافقية وضمان تبادل البيانات بالصيغة المطلوبة.

إستخدام طبقة جلب البيانات وتحويلها وتحميلها إلى مستودع البيانات لضمان صيغة بيانات معيارية، بالإضافة إلى إستخدام قاموس البيانات وتقسيمها حسب الإختصاص لتسهيل إستخدام مستودع البيانات من أصحاب المصالح المختلفين وتزويدهم بدخول فعال لهذه البيانات وتحليلها. لحساسية هذه البيانات وتعقيدها ينصح هذا الإقتراح بتبني أدوات التعلم الآلي و إستخراج البيانات للحصول على رؤى وأفكار ذات دلالة والتي لا يمكن إستنباطها من خلال التحليل البشري أو التقليدي من أجل إدارة وعلاج أفضل. كما ويقترح إستخدام chatbot لتزويد المستخدمين المعنيين بدخول سلس للبيانات المناسبة حسب الحاجة .